LOUIS PASTEUR

THE FRENCH SCIENTIST WHOSE STUDIES PAVED THE WAY TO THE DISCOVERY THAT INFECTIOUS DISEASES ARE CAUSED BY GERMS

BRIEFER

# PHYSIOLOGY AND HYGIENE

## WITH PRACTICAL EXERCISES

BY

BUEL P. COLTON, A.M.

AUTHOR OF "PHYSIOLOGY, EXPERIMENTAL AND DESCRIPTIVE"
"ZOÖLOGY, DESCRIPTIVE AND PRACTICAL," ETC.; AND
LATE PROFESSOR OF BIOLOGICAL SCIENCE IN THE
ILLINOIS STATE NORMAL UNIVERSITY

AND

LOUIS MURBACH, PH.D.

DEPARTMENT OF BIOLOGY, DETROIT CENTRAL
HIGH SCHOOL

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## COLTON'S PHYSIOLOGIES

**PHYSIOLOGY AND HYGIENE**
Briefer Course, revised by Louis Murbach. With practical exercises; illustrated in colors.

**PHYSIOLOGY: Experimental and Descriptive**
For Normal Schools and Colleges. Illustrated in colors.

**PRACTICAL PHYSIOLOGY**
Laboratory Exercises in Physiology. Illustrated.

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This consists of the Briefer Course and the Practical Physiology bound in one volume.

**ELEMENTARY PHYSIOLOGY AND HYGIENE**
For Grammar Schools. Illustrated.

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# PREFACE

In accepting the invitation to revise Colton's Briefer Course in Physiology, the reviser felt that, if this could be satisfactorily done, it would be a service to those who have so long found the book teachable and who would still retain it if it were brought up to date. And to those who have not known the merits of Professor Colton's books — in which his teacher's instinct is everywhere apparent — it is hoped that the revision, containing all of the original pedagogical value, will appeal on the ground that the first edition has stood the test of fourteen years of continuous use, and that, in its present form, it embodies the newer data as far as they can be taught in the first two years of the high school.

One of the radical changes in the book has been the unifying of correlated topics, bringing them together from different chapters into one more comprehensive chapter. This does not mean that the book is increased in size or in difficulty of understanding.

The content and arrangement of the book is such that it can be used for one-third year, one-half year, or a whole year's work. In schools of "three terms," Chapters I–V, VII, XII, and XVII, with some demonstration exercises by the teacher, may be done in one term. Where there is one-half year, Chapters I–IX, XII, XIII, XV–XVII, with corresponding exercises may be profitably selected. Or, teachers may take more time for exercises and omit Chapters VI, X, XIV, and XVII. In any case, time may be saved by omitting "Ailments or Diseases" at the end of the chapters.

In a year's work all the exercises and the text can be accomplished. In such case, again, the work would better be laid out so that the pupils in the first semester might have a more or less complete view of the subject, in case they do not continue the course after one semester. The first semester, therefore, might cover Chapters I–V, XII, XVI XVII, and the corresponding exercises.

Finally, those teachers who desire more structure may lay stress on Chapters IX–XIV; those to whom hygiene appeals most strongly will

find abundant material at the end of each chapter and in Chapters XV, XVI, and XVII, entire.

In a half year's work the reviser has found it very desirable to assign the short Chapter (XVII), First Aid in Emergencies, at the beginning of the term so that the members of the class may have a chance to practice under the direction of the teacher and report cases during the remainder of the school term.

In the appendix are further suggestions on the writing of exercises; on specimens and apparatus; also on books of reference. After considerable reflection, it was decided to include neither magazine articles for reference, nor the more or less ephemeral literature on physiological subjects. Only a few of what are considered the most helpful references are given in the appendix. In this direction, much is left for the teacher to suggest in the way of topical reading, *e.g.*, the "Black Hole of Calcutta" when studying respiration, or the "Life of Laura Bridgman" when studying the organs of special sense.

Most of the original illustrations have been retained, but thirty-one are new in this edition. Of these seven were engraved for the revision: 9, 33, 42, 62, 99, 112, 113. No. 9 is based on a student drawing, No. 33 is from a lantern slide of unknown origin, 42, 62, and 99 are after Gegenbauer, 112 and 113 are after Michigan Public Health Bulletin. The others are from books by the publishers where their sources are acknowledged. It is hoped that these will aid materially in understanding the subject matter.

The summaries at the end of each chapter have been replaced by very full questions covering the important topics. This change is based on the experience that, not infrequently, careless pupils used the summaries instead of the text in a hasty preparation of the lesson.

Finally, for all shortcomings, neither the original author nor those who have given help in the revision are responsible, but solely the reviser.

Acknowledgment is due to Miss Grace F. Ellis, of the Grand Rapids Central High School, for some paragraphs in the chapters on the Nervous System and the Voice, taken from her suggested revision of those chapters; to my associate teachers for suggestions on the manuscript and the exercises; to the publishers and critics for helpful advice and for their critical and thorough reading of the proofs; and to my wife for invaluable help given throughout the preparation of the revision.

L. M.

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# PHYSIOLOGY AND HYGIENE

## CHAPTER I

### INTRODUCTORY

**How to read a Book.** — If the reader wishes to be convinced of how much he learns from any book, a good way is to make an inventory of the knowledge that he already has of the particular subject that he is about to study. When he has set down all the facts he already knows concerning it, and has read through the book, the facts known before will appear to him in new light, and new facts will be added.

**Make an Inventory.** — A few questions will suggest how to make such an inventory for physiology. Can you draw an outline of the body, and place the principal internal organs in their right position? Could you tell where the pit of the stomach is, or the base of the heart, or where the tips of the lungs are? Where would you feel an enlarged liver? What is the use of these and other important organs?

**How the Body is to be Studied.** — There are two good ways of proceeding in getting an education. One is to go from simple ideas to more complex ones, and the other from the well-known to the unknown. The microscopic structure and the chemical composition of the body would seem to be both unknown and complex.

**Organ.** — All are familiar with the fact that parts of the body do special work; *e.g.* the ear is for hearing, the eye for

seeing, the nose for smelling. Any part of the body doing a special work is called an *organ*. Make a list of various organs of the body.

**Organism.** — Our bodies are organisms, *i.e.* they are made up of organs each of which has a special work or activity. When we say that animals or plants are *organisms*, we mean that they are made up of organs. Could we say this of a rock?

**Function of Organs.** — The work that any organ does is called its *function*. Other words for function are work, activity, duty.

"Of the senses five have we,
To hear, feel, smell, and taste and see."

This couplet does not name the organs, but helps us to remember what they do.

## Studies Dealing with the Body

**Physiology.** — The study of the activities or functions of living organs (animal or plant) is called *Physiology*. The word physiology means merely a discourse on nature, but has come to have the special meaning given it above. How would you define human physiology?

**Hygiene.** — How to keep the organs of the body in good working condition, *i.e.* in health, is another study called *Hygiene*. This is personal hygiene; public hygiene would naturally refer to the health of the community, having to do with contagious diseases, water supply, clean streets, etc. Hygiene is really the more important study, and should receive much attention, for is it not a good thing to be well and strong?

The study of hygiene, then, is the application of physiol-

ogy. To know how to keep organs in the best working condition we must learn their normal action or function, and, to some extent, their make-up or structure.

**Anatomy.** — The understanding of the function of an organ depends also upon a knowledge of its structure. The study of the structure of the body and its organs is called *Anatomy*. Thus when we learn that the heart is a muscular bag (anatomy), pumping the blood through the arteries by muscle action (physiology), we know that excessive exercise would overwork and injure it (hygiene).

## The Living Substance

**Protoplasm.** — In order to understand the internal activity of an organ, we must go deeper, and we shall find this activity in the living substance itself. Rocks or clay have no activity — are not alive, as are animals and plants, which are made chiefly of living substance. This living substance is called *protoplasm*, from two words meaning

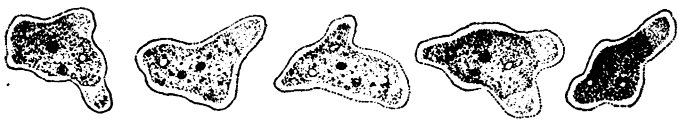


Fig. 1. — Ameba; changes in form, drawn at short intervals

"first-molded," because it is the only substance of which living beings are first formed. Protoplasm is the most important subject to bear in mind in the study of physiology, as all normal activities of the body take place in the living protoplasm. In order to understand what protoplasm does in keeping alive the body that it forms, it is best to study it in one of the simplest of animals ever discovered — the microscopic *ameba*. (See Fig. 1.)

**The Amebas.** — When we examine under a microscope a drop of water containing *amebas*, we can see these organisms of almost pure, jelly-like, colorless protoplasm slowly creeping about by snail-like movements. If the *ameba* bumps into another microscopic animal, it recoils. The *ameba* is evidently sensitive; it can feel. Now it may change its course, as it has the power of motion. It creeps on. But what is the object of its ceaseless search? We might guess, but we shall see if we watch closely. Presently it comes upon a microscopic plant or a particle of plant food, but it does not recoil as before.

**Feeding and Digesting.** — The *ameba* appears to pass over the food; but no, the particle seems to be carried along by the *ameba*. In fact it has taken up the particle, that is, has swallowed it. We have seen the *ameba* taking food. Now if we follow it long enough, we shall see this particle becoming smaller and smaller, and if it is all digestible, it will disappear — be absorbed.

**Giving out Waste.** — Assuming that the particle was not entirely digestible, the remains will be left behind — rejected. During this time we might have noticed a dull, pink globule — a kind of bladder — in the protoplasm of the *ameba*. From time to time this globule closes up, squeezing its liquid waste contents out of the nearest side of the body. So even the *ameba* has two ways of getting rid of — or excreting — waste matter, as it is called.

**Breathing.** — What else can the *ameba* do that is similar to what our bodies do? Does it breathe? This may be answered by putting some *amebas* into water containing oxygen but no carbon dioxide. After a time tests will show that the oxygen in the water has been used and carbon dioxide given out, proving that the living *ameba* breathes.

The *ameba* is a unit mass of protoplasm; it is a cell, which breathes, takes food, gives out waste, is sensitive, and can act in other ways according to its condition. These activities seem to be regulated by a small, kernel-like, glistening portion of the protoplasm, called the *nucleus*.

**Cells.** — One may now wonder if the living substance of our organs is anything like the *ameba*. The active parts of all our organs are made up of countless single masses of protoplasm called *cells*,[1] and in these the real activity of the organ takes place. They are microscopic in size and of various shapes in different parts of an organ. In muscles the cells are somewhat spindle- or fibre-shaped. (Compare Fig. 2.) This shape is best suited to do the contracting and pulling for our bodies. Surface cells, that may be scraped from the inside of the cheek, when examined under a microscope, are seen to be flat. (See Fig. 3.) Cells of the body that cover surfaces are of this general shape. Are not covers for things usually flat? Now we can understand what is meant when we are told that the shape of groups of the body cells is fitted for their use or function. Conversely, cells that are similar in shape generally have similar uses.

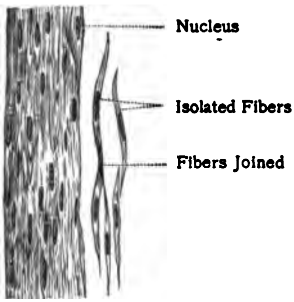



Fig. 2. — Plain (unstriated) muscular fibers from the bladder — a tissue

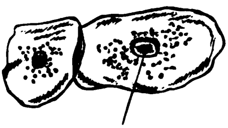



Fig. 3. — Cells from the Inside of the Cheek

**What Tissues Are.** — Wherever a group of like cells

[1] When first discovered in plants, only the compartment or cell wall was seen; the clear, live protoplasm was overlooked.

does a common, or similar, work it is called a *tissue*. In fact, organs are made of groups of tissues. A tissue may be defined as an aggregation of similar cells devoted to a common work. Although the cells are closely packed together, each cell leads, in one sense, an independent life. But all work together to maintain the life of the body. The cell is like the individual in a community. Each lives for itself, yet all work together for the common good.

**The Physiological Division of Labor.** — We are aware of the advantages of division of labor in a community. If each person learns to do one thing well, all work together economically for the common good, time is saved, and better goods are produced. In the body there is a division of labor similar to that of a community. Each organ has its own work to do, and all work together for the common welfare. The cells of each tissue have certain properties and peculiarities of form differing from the form and properties of the cells of any other tissue. While the general structure of all cells is essentially the same, and while they all have certain properties in common, each has some one kind of work that it can do well, and to this work it devotes itself. The nerve cells receive impressions from the outer world, carry nervous impulses, and control the various activities of the body. The muscle cells have as their work contraction for the production of motion. All the cells must take food for themselves and grow.

In an animal of a single cell, like the *ameba*, the one cell must do everything for itself. All animals begin their individual life as an egg, which is, in fact, a single minute cell. This grows and divides, forming two cells. By repeated division there accumulates a mass of cells. These take on the arrangement peculiar to the kind of animal from

which the egg came. But as the cells increase in number, one group of cells takes up one part of the work of the body, other cells another part of the work, and so on.

In studying history (sociology) we have to deal with the individual, the community, state, and the nation. The cell is an individual, the tissue is a community, an organ is the state, and the body is the nation. Let us proceed to study the nature of the combined actions of these individuals in the organism called the body.

**Systems of Organs.** — Organs, while in general constituting the body, are arranged in groups to perform the seven chief activities that we all have to perform to live. The groups of organs are called systems. Some of these life activities were foreshadowed in the life of the *ameba.* They are: 1. The whole process of feeding and the corresponding group of organs is called the *digestive* system; 2. The distribution of the blood and lymph, the *circulatory* system; 3. The process of breathing, performed by the *respiratory* system; 4. The movements of the body, brought about by the *muscular* system; 5. The control of practically all activities by the *nervous* system; 6. The supporting and leverage of the parts of the body, due to the *skeletal* system; 7. Ridding the body of liquid wastes by the *excretory* system.[1]

### QUESTIONS FOR REVIEW

1. What is one good way of learning from a book?
2. State the difference between an organ, a tissue, and a cell.
3. What is their relation to the organism or body?
4. Tell something of the physiology, the anatomy, and the hygiene of the heart, to show the teaching of these studies.

[1] At the option of the teacher these systems of organs may be passed over at this time and used later for review.

References for general reading are given in the Appendix.

5. Under which one would "function" be studied? Why?

6. What is protoplasm? Why is a knowledge of it important in human physiology?

7. What are the activities of protoplasm as learned from an *ameba?*

8. With which of our activities do they compare? What others have we?

9. What are the systems of organs? What is meant by "physiological division of labor"?

**EXERCISES**[1]

1. *To Illustrate Living Protoplasm and Amebas and Cells.* —Partly decayed water-lily leaves and stalks kept in a covered dish full of water for several days or weeks are the most fruitful source of *amebas.* The ooze from ponds or ditches that do not dry up also furnishes *amebas.* A drop of the scum from the surface is mounted on a slide, covered, and examined, first under the low and then the high power of the microscope. If *amebas* cannot be found, other animalculæ in the above infusion will illustrate the colorless jelly-like appearance of protoplasm. Protoplasm may also be seen in the cells of the thin skin between layers of a sprouted onion. Here the plant cell walls are very conspicuous and there is only a lining of protoplasm sending out strands to connect with a pale globule, the nucleus. In these strands of protoplasm movement of granules may be seen, with a ⅛ inch objective.

2. *To Illustrate the Form of Pavement or Epithelial Cells of the Skin.* — From the inside of the cheek a little material is scraped with a wooden toothpick, mixed with a drop of water on a slide, and covered with a cover glass. This is now examined with the low and the high power (⅛ in.) of the microscope. A little dye like methylin blue will show nucleus and dead cell body similar to Fig. 3.

3. A tiny piece of beefsteak as big as a pinhead torn to finer shreds in a drop of vinegar and covered and examined as in (2) will show fine cross striping of the muscle cells, similar to Fig. 74.

[1] In the Appendix there are suggestions on the experimental exercises.

## CHAPTER II

### FOODS: THEIR COMPOSITION AND USES

**Why we Eat.** — Hunger is the natural craving of the body for the food that it needs. This wholesome craving is an important sensation of the body, possessed by all animals, including man. It leads to the search for food and the voluntary taking of nourishment. Among plants this is not the case. If animals did not become hungry, they would not eat and would die. In the case of man this does not happen because he knows that if he does not eat he cannot live, and so he takes food at regular intervals, even though he may not be hungry. While the sensation of hunger is due to a nervous reaction from an empty stomach, it is, after all, an indication of the need of food substances in the tissues, *i.e.* in the living parts of the body.

**Why we need Food.** — We are using our strength while we are active, and we are constantly losing the warmth of the body. Besides the muscular work that we may do, there are internal processes (activities) that make over the food that we eat into strength and warmth and new living substance. In consequence of all these activities the tissues slowly wear out and must be renewed. Besides, all young animals and people grow, and growth means the building of more new living tissue. This is the physical condition of the individual: living, growing, working. We may say that we need food (1) to increase the size of the body, as in the growing boy or girl, (2) to replace

the tissues worn by the work of living, and (3) to supply us with muscular energy and heat.

**The Staples or Essentials of Meals.** — If one were asked to tell what are the staples or main things that occur quite regularly in our meals, what would he answer? In all probability he would say, "meat, potatoes, bread and butter, or milk." He might add salt, and something to drink, if the milk were not a part of his meal. Could a person make a meal of butter alone, of potatoes only, or even of bread or meat alone? We might agree to leave out the potatoes or the bread or the butter. Then, even if one could satisfy his hunger for one or two meals with meat or bread alone, he could not keep healthy on such a diet. If we were to read the reports of foods used by civilized people in all countries, we should learn that their meals contain about the same substances that are contained in meat and potatoes, or bread and butter, or milk.

**Composition of Foods.** — This fact is significant, and it is important to know what these substances are. If we should classify butter correctly, we should say that it is a fatty substance. The diet of all races includes some such substance. In Arctic regions the inhabitants use large quantities of fat (blubber) besides meat and herbs. In Italy much olive oil is used. Many seeds that are used for food, *e.g.* corn, peas, and beans, contain fat.

Most people know that there is much starch in bread and in potatoes. Starch is present in all vegetables and in larger quantity still in all grains. We may ask, "Is starch one of the substances (like fat) that is taken at every meal in some of the various kinds of food we eat?" Yes, but we must go a step farther as starch has a partner or substitute. It has been found that sugar answers the same

purpose as starch in our food. In fact all starches that we eat are usually changed to sugar in the body. From their similarity in chemical composition (carbon, hydrogen, oxygen), starch and sugar have been called *carbohydrates*; therefore either or both of them, when referred to as a primary food substance, is called a carbohydrate.

For the primary substance in meat food a new name is used. In all foods similar to lean meat and the curd part of milk and cheese, the primary food substance is now called *protein*;[1] some years ago it was called "proteid." In each of the above foods the protein has a special name: *myosin* in meat, *albumin* in eggs, and *casein* in milk and cheese. Carbohydrates and fats also have special names indicating their origin. Now these pure substances in our foods — proteins, fats, and carbohydrates — nourish the body and have been called *nutrients* or foodstuffs.[2]

**Other Nutrients.** — While every one knows the desirability of water and common salt in our food, there are other mineral substances, similar to common salt, and in fact called *salts*, that are necessary for building up and repairing the skeleton and the teeth, and for the proper working of muscles and living tissues in general. "Complete withdrawal of any one of these (salts or water) constituents would cause the death of the organism."[3] Water enters into the composition of all the tissues of the body to such an extent that two thirds of the weight of the body, roughly speaking, is water.

**Nutrients Defined.** — The nutrients, or foodstuffs, stated

[1] Protein is from a Greek word meaning "first" (*protos*).

[2] The name "alimentary principles" has also been used.

[3] Howell's *A Text-Book of Physiology*, 1912. The same may be said of protein, though not of carbohydrates and fats.

in the order of their importance, are proteins, mineral salts and water, carbohydrates, and fats. The reasons for this order will be given more fully under the topic Nutrition. If we agree, now, that nutrients are the substances in the foods taken into our bodies that build up the tissues and enable us to live and work, we shall have an acceptable definition. Most articles of food lack one or more of the necessary kinds of nutriment. Most plant substances have starch and a little protein; while milk has protein, fat, sugar, and salts. At least one nutrient is needed to constitute a food. While there are many foods, there are but five nutrients, one or more of these occurring over and over in all foods.

### Characteristics of Proteins

(1) Nearly all the proteins are precipitated or curdled from a liquid condition by certain agents or substances. This agent is different for different proteins; *e.g.* egg albumin and some others are coagulated by heat, serum albumin of the blood clots when blood comes in contact with any foreign substance, the casein of milk is curdled by acids (vinegar) and by the rennet of the stomach. (2) They give off a very offensive odor when they putrefy. When they are moist and warm, germs decompose them; *e.g.* meat "spoils." In this condition they are poisonous. (3) Proteins are made up of the same chemical elements that compose our tissues, viz. nitrogen, hydrogen, oxygen, carbon, and sulphur. From the third characteristic the importance of proteins in our foods is apparent.

**Foods Containing Protein.** — The principal protein-containing foods are lean meat, fish, eggs, milk, cheese, and some seeds which abound in the vegetable proteins.

**Animal Proteins.** — Lean meat has about 20 per cent of protein, the rest being chiefly water. Beef and mutton are more easily digested than veal and pork. It is better to buy meat from a very fat animal than from a lean one, for, although there is slightly less protein in the meat from a fat animal, this loss is more than made up by the presence of fat, and such meat is more easily digested. There is more nourishment in round steak than in tenderloin.

*Fish* once a week is a good rule for health. Although, as a rule, salted and smoked meats are less easily digested than fresh, salted codfish is a nourishing and economical food. Fish is not a special brain food as some believe.

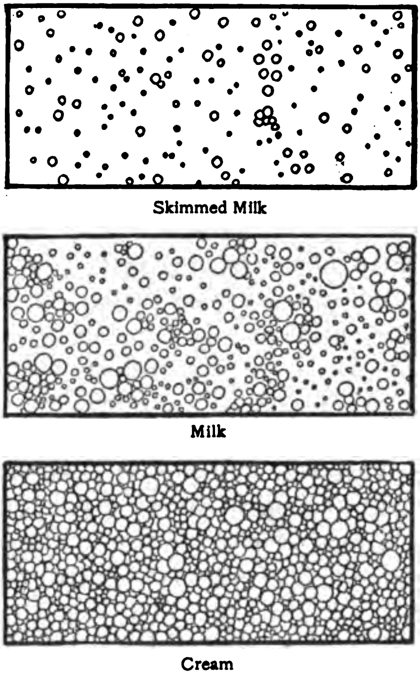


Fig. 4. — Fat globules in milk and cream

*Eggs* contain considerable protein. The yolk has a large amount of fat. The sulphur compounds of the yolk cause the nauseating odor of rotten eggs. Compare the calories yielded by an egg and a piece of bread. (See Table, page 29.)

*Milk* is a good food in that it contains all the kinds of foodstuffs, and in the right proportion for the young

mammal. But the proportions are not right for the adult. An adult would need four and a half quarts daily, and then he would not get enough carbohydrates (represented in milk by the sugar). The fat in milk is in the form of minute globules, which can easily be seen under the microscope. Each of these oil droplets is surrounded by a thin envelope of albuminous matter, by means of which it is enabled to remain suspended for some time instead of rising quickly to the surface. Such a mixture of oil in a liquid is called an *emulsion*. When cream is churned, the albuminous covering is removed and the butter "gathers."

*Cheese* is very rich in protein, much more so than lean meat. Yet, as it is rather difficult of digestion when eaten alone, we regard it more as a luxury, while in many parts of Europe it is largely used as food, taking the place of meat. It is an inexpensive food, and might well be used more extensively, especially by laboring men. It is said to be more readily digested when taken with other food.

**Vegetable Proteins.** — Peas and beans (dried) contain more protein (legumin) than meat, and all the cereals — *i.e.* corn, wheat, rye, oats, barley — contain some protein (gluten), especially in the bran.

## CARBOHYDRATES

**Their Nature.** — On boiling in water (or mixing with a little alkali) carbohydrates form gelatinous mixtures (pastes), but this is not to be confused with the coagulation of proteins. While starch and sugar are the best known carbohydrates, gums and cellulose are in the same group. Carbohydrates are first produced by plants, which can change one carbohydrate into another. This the body

cannot do, though it can make "muscle sugar" out of starch, sugar (or protein). As their name implies, the carbohydrates are composed of the chemical elements carbon, hydrogen, and oxygen. Upon decaying (fermenting), many of them have a sour odor due to the formation of alcohol and acid. Next to the proteins and salts, they are the most important nutrients, as the carbohydrates can replace the fats better than they can be replaced by the latter.

**Foods Containing Carbohydrates.** — Grains, seeds, fruits, tubers, and roots are the ordinary sources for the carbohydrates used as food by man. In fact, when it is understood that a cabbage is a huge bud, cauliflowers are modified blossoms, lettuce and celery represent leaves, and the onion and potato are modified stems, we see that all parts of the plant may be sources of some carbohydrate.

**Wheat, Flour, and Bread.** — Besides much starch, wheat bread contains considerable protein. (See Table, page 29.) It was formerly supposed that white wheat bread did not contain enough protein, because certain digestive troubles were remedied by graham bread or whole-wheat bread. It is now known to contain as much protein as can be digested, so it is not the more abundant protein that whole-wheat bread furnishes in its bran. The bran probably contains some salts necessary for the better digestion of the wheat starch, and herein lies the greater value of whole-wheat bread.

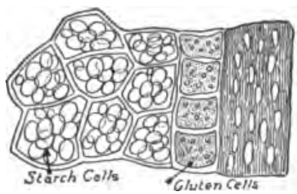


Fig. 5. — A grain of wheat. Analyzed to show starch and gluten

**Corn.** — While there is sugar in sweet corn, field corn, which is the source of corn meal, has, besides the starch,

some fat and protein. On this account certain writers have recently made much of it as an inexpensive source of nutriment. The nutriment is there, but it is less readily digested than similar preparations of wheat, and consequently less desirable as a food for indoor workers.

**Rice.** — The importance of rice may be seen in the fact that in India, China, and the Malayan islands it is often almost the exclusive diet. It contains less fat and protein and more starch than other grains, and therefore is better for people in warm climates. Before it was discovered that beriberi was caused by an exclusive diet of polished rice, a remedy for this disease had been found in Japan in the use of a diet of half rice and half barley (unpolished). Later still it was found that the trouble was removed by using an extract of rice bran with the diet of polished rice. (See paragraph on Wheat.)

**Vegetables.** — Potatoes contain about 18 per cent starch, 1½ per cent protein, a trace of fat, 80 per cent of water and indigestible material, and .6 per cent mineral matter in the form of salts, phosphates, and potash. There are also present some organic acids, to which the flavor is said to be due. In spite of its relatively low food value, the potato is our most valuable vegetable, on account of its abundance, the ease with which it can be preserved, its mild flavor, and the readiness and the variety of ways in which it can be cooked. In connection with other foods it is one of the most easily digested, and the least expensive starchy food that we have. Old and sprouting potatoes may develop a poison, *solanin*, and should be used only cautiously, or not at all. In the South, the sweet potato largely replaces the white potato as a regular article of food.

**Carbohydrates and Salts.** — The chief nutrient in other vegetables, such as greens, celery, cabbage, turnips, and other roots, etc., is starch and, in some, sugar. But their greatest value lies in the salts and flavors they have. These should be conserved as much as possible in preparation by boiling. Some contain more than 2 per cent mineral matter, and fresh lima beans may have 7 per cent. Almost all foods contain some salts and water. Cabbage and root vegetables are especially valuable in the winter season when we cannot get fresh vegetables, such as greens. The woody matter in vegetables is of value in adding bulk to the mass of material to be passed by the intestines, as bulk increases peristaltic movement in the latter. Too concentrated food makes the intestines sluggish. Scurvy, a skin disease due to too much dry and salty food, formerly attacking sailors and seamen out on long voyages, has been cured or prevented by eating an abundance of vegetables. Sir Francis Drake is said to have kept his men in fighting trim through this discovery, while the enemy lost more men by scurvy than in battle.

**Fruits.** — Ripe fruits have more sugar (fruit sugar or glucose) than starch. Bananas also have much starch, and on this account are not easily digested. Grapes are the most nutritious fruit. But fruits are probably most useful to us on account of their flavor, — due to aromatic bodies, — and of their salts and the peculiar fruit acids. These stimulate digestion and peristalsis. (See page 68.)

## FATS

The nutrient term *fat* includes not only tallow, lard, and all kinds of fats, but also all edible oils. Fats differ from the other nutrients in burning very readily and giving off

more heat. This is because they have less oxygen in combination and can take more on being heated to the burning point. The chemical elements of fat are carbon, hydrogen, and oxygen, the same as in starch, but not in the same proportion.

**Sources.** — Both plants and animals can produce fats, *i.e.* make them out of the elements carbon, hydrogen, and oxygen.

*Animal Sources.* — In all meat foods there is some fat. The cream of milk and the yolk of eggs yield fat. Cheese also contains more or less fat, and butter is practically pure fat. Of the animal fats butter is the most easily digested, and is agreeable to most people. Artificial butter is made from tallow, lard, some cream, and cotton-seed oil, and is really better than poor or spoiled natural butter.

*Vegetable Sources.* — Many seeds, and especially the grains, contain some fat. The oils most commonly used for food are olive oil (salad oil) and cotton-seed oil.

## WATER

The water supplied in cities is usually examined periodically by an officer of the Board of Health, whose business it is to warn people when the water is in any way dangerous to drink, *e.g.* on account of typhoid fever germs or organic matter. In the country and in summer camping or outing grounds, each household must look out for itself. Discolored water and that which has an odor of decay should be avoided. Water that is merely roily may not be harmful if it can be filtered or if it is allowed to settle.

**Water in the Body.** — Water constitutes about two thirds of the entire weight of the body. It constitutes the bulk of the liquids found in the body, blood, lymph, sweat, saliva,

bile, etc. Water is the solvent and carrier of all the material of the body. Hence we need a large amount of it; of course we must remember that we get a good deal of water in most of our solid foods.

**Rain Water.** — Water as it comes from the clouds is pure. After enough rain has fallen to wash the air, rain water is pure, and if caught on a clean roof (especially a slate roof) and kept in a clean cistern, it is good drinking water.

**Impurities in Water.** — The great source of danger is from what are called "organic" impurities. Bacteria will not live and grow in pure water. They must have something on which to feed and grow. But in water containing a large amount of decaying animal or vegetable matter they are likely to abound. The most dangerous sources of contamination are cesspools and sewers. Water may be contaminated by such material and not have bacteria in it, but it is very likely to harbor such foes.

**Water and Typhoid Fever.** — Typhoid fever is now known to be caused by germs in drinking water or milk. The dejecta of any one who has had the disease may find their way into the drinking water. In many cases this has been clearly proved. Of course the dejecta of all such patients should be either destroyed or thoroughly disinfected. (See Appendix.)

**Boiling Water.** — When one cannot get good drinking water, or when away from home where the water is of doubtful purity, it is better to boil the water before using it, either as a drink or in preparations of food that are not to be thoroughly cooked. It seems to be proved that it is better to heat the water twice nearly to the boiling point, nine hours apart, than to boil hard once only. The first

heating may start the resistant germs into more active life, causing them to sprout (so to speak), and a *second heating several hours later* may easily kill them; whereas it has been proved that one hard boiling will not always kill the germs. The peculiar taste of boiled water, due to the removal of air by boiling, may be remedied by shaking it in clean half-filled bottles until the natural taste has been restored.

**Ice Water.** — Although bacteria will not develop in a cold place, they are not killed when frozen in water, as was formerly supposed. Further, ice, in forming, does not throw out all the impurities, as was at one time supposed. So it is not safe to drink water formed from melted ice unless the water of which that ice was made was good water. The ice taken from ponds is not safe. If ice is made artificially from suitable drinking water, of course the melted product will be essentially unchanged so far as the composition is concerned. Water may be cooled by placing even impure ice around it, thus giving the desired temperature without any admixture of a dangerous element.

**Cautions as to Drinking Water.** — If one is used to tea and coffee, it is safer to content one's self with these, and not drink much water till that which is safe can be obtained.

In hot weather, especially for those who are engaged in hard work, it has been found that a little oatmeal stirred in the water is beneficial.

When overheated, avoid drinking much cold water. Repeatedly rinse the mouth with cool water, and swallow very little. This is the way trainers manage a horse at a race, and it is sensible to treat a man as carefully.

All water vessels, such as water bottles, pitchers, etc., should be cleaned periodically with vinegar to remove the lime. Water kept in porous earthen jugs or pitchers keeps

cooler than in ordinary vessels, because of the evaporation of the water that soaks through.

The cup from which everybody drinks has been banished from public use in several states, and in all large cities, and it is hoped that it will disappear elsewhere. Diseases have frequently been spread through it. On your travels learn to make a cup of paper carried for the purpose, or of clean newspaper. (The Appendix tells how to fold the paper.)

## Non-nutritious Drinks

*Tea* owes its stimulating effects to a substance called *thein*. This is a stimulant to the nervous system, but if not too strong is not followed by a subsequent depression. Tea that is too strong is likely to produce nervousness and dyspepsia. Boiling the tea leaves also brings out the tannic acid that they contain, and produces dyspepsia.

*Coffee* owes its stimulating effect to a substance called *caffein*, which is considered identical with thein. Coffee acts as a restorative after hard labor, seeming to retard the wastes of the tissues and food. It is used in the army, not as a luxury, but as a matter of economy in the amount of food supply. Coffee, used to excess, frequently causes palpitation of the heart.

*Beef tea* and various beef extracts are beneficial. There is not enough nourishment in them to maintain strength without other food. Therefore beef tea alone is not good for an invalid. The nutritive value of beef extracts has been overestimated. Their value is probably more in their stimulating than in their nourishing effect. It has been said that a dog would live longer without food of any kind than he would if given beef tea and nothing else. But many of the soups and drinks made from these preparations

are very beneficial. They refresh the tired system wonderfully. If the man who feels "fagged out" and takes a drink of liquor to "brace him up," as he says, were to take a cup of hot bouillon, he would find himself braced up for the time, without any bad reaction or permanent injury to the system, which follow the use of alcohol.

## Nutritious Drinks

*Cocoa, Malted Milk, Milk.* — While cocoa and chocolate also contain a stimulant called ***theobromin***, these drinks do not injure most people as much as do strong tea and coffee. But unlike tea and coffee, cocoa and the preparations from cocoa, known as chocolate, are true foods by virtue of the fat that they contain.

Malted, peptonized, and pasteurized milk make valuable drinks for invalids and dyspeptics. "Cambric tea" — hot water with sugar and cream or milk or with a pinch of salt — is excellent for "toning up" a weak stomach before a meal. It will relieve headache and indigestion.

## Accessory Foods

**Desserts.** — Many substances that we generally call desserts — pie, cake, puddings, jellies, etc. — are additional food, as they often contain nutrients. They are taken mostly for finishing a meal, and in reality they assist the digestion of the meal. They are more than mere delicacies, since the wheat flour used in making pie and cake contains protein and starch; in puddings, eggs and milk are used; and jelly — with all the rest — has much sweetening, which means carbohydrate food.

**Condiments.** — In the preparation of food certain substances are used that improve its taste and flavor. These

are salt, pepper, and mustard; various sauces; extracts, such as vanilla, etc.; and acids, such as vinegar, lemon, etc.; these are commonly known as condiments.

Hot spiced sauces overstimulate the flow of the digestive juices and impair health. They may lead to drinking, which is not always harmless.

## Cooking

*Cooking* is designed to make food more palatable and more digestible. Some foods, such as eggs, are as digestible before they are cooked as after, often more so, as they are sometimes very badly cooked. But many foods in the raw state are unattractive, or even repellent, whereas cooking usually develops an agreeable odor and taste. Cooking should soften the harder and tougher tissues, such as cellulose in vegetables, and the connective tissue of animal foods. Cooking starch causes the starch grains to swell and burst, and makes the starch much more digestible.

**Making Soup.** — If meat be cut into small pieces and put into cold water, and the water gradually warmed, the soluble material of the meat may be extracted, and this is the principle followed in making soups.

**Boiling Meat.** — But if we wish to cook the meat itself, the juices should be retained instead of withdrawn. For this purpose boiling water is poured over the meat to coagulate the outer layer and prevent the extraction of the juices.

**Baking, Roasting, and Broiling.** — The same principle applies to baking, roasting, and broiling. The outside is subjected to high heat at the beginning of the cooking, which forms a layer nearly impervious to the nutritious material inside. In these modes of cooking it is very de-

sirable to reduce the heat applied after the first few minutes, so that the interior may be more gradually cooked; this is, perhaps, especially true in broiling.

**Frying.** — Frying, as ordinarily done, is not a good mode of cooking; in fact, is often very bad, as the food is frequently penetrated by fat and rendered very indigestible. But true frying, that is, by immersion in boiling fat, is a good mode of cooking. This coagulates the albuminous substance on the outside, keeps in the nutritious juices, and prevents soaking with the fat. Often the food to be thus cooked is first coated with white of egg, which is very quickly coagulated, and helps to form a protecting outside crust.

**Disadvantages of a One-sided Diet.** — In order to get enough nitrogen from bread alone, one would have to eat about four pounds a day; meanwhile twice as much carbon as is needed would be taken, thus throwing an undue amount of work upon the digestive organs. Again, one would need to consume about six pounds of meat to get the requisite amount of carbon, and six times as much nitrogen as is needed would be taken; to get rid of this extra nitrogen would severely tax the kidneys and liver.

**Vegetarians.** — The so-called "vegetarians" recognize the need of protein food, and most of them seek protein in eggs, milk, and cheese. But these are animal products, and the name "vegetarian" is inconsistent. They are merely "anti-meat eaters." If they do actually succeed in getting enough proteins from the legumes and the grains, the complete digestion of which is difficult, they are, as Professor Martin says, to be congratulated on having digestive powers that can stand such a strain.

**Necessity of a Mixed Diet.** — Our experience, together

with the results of experiments on animals, teaches that we could not live long if fed on any one class of foodstuffs alone. We must take a representative of each of the groups of nutrients. We have noticed that most of our foods already contain more than one foodstuff. We so combine them as to get suitable proportions. Thus we eat bread and butter (a small amount of fat with a large quantity of starch and a little gluten), meat and potato, crackers and cheese, pork and beans, egg on toast, bread and milk, rice and fowl, macaroni and cheese; they "go well together" chiefly because they are complementary.

**Proper Diet.** — While common experience has led people to adopt a mixed diet, the proportion of the different foodstuffs is not always what it should be. The desirable proportion (exclusive of water) may be roughly stated as about 1 part of protein, 1 part of fat, and 3 parts of carbohydrates. But this will vary somewhat with the amount of work done and other varying conditions. In good health exact proportions of nutrients need not be eaten at each meal, or even every day, so long as the diet is varied and the general proportions fairly kept.

**The Guiding Principles.** — There must be protein enough for tissue growth or repair. If there are not carbohydrates enough for activities or fat enough for heat, the tissues are broken down to supply the deficiency, and we lose flesh. The carbohydrates and fats cannot take the place of protein, but they can save the protein when they are abundant enough. To express this Professor Howell has called them "protein sparers." (See topic, Care of Foods, page 31.)

**The Proportion of Nutrients.** — When the amount of a nutrient, or the amount of its chief element, taken in is balanced by the amount of that element in the excretions or

wastes of the body, the body is said to be in equilibrium as to that food. The body may be in nitrogen equilibrium on different amounts of protein, *e.g.* 60–120 grams per day.

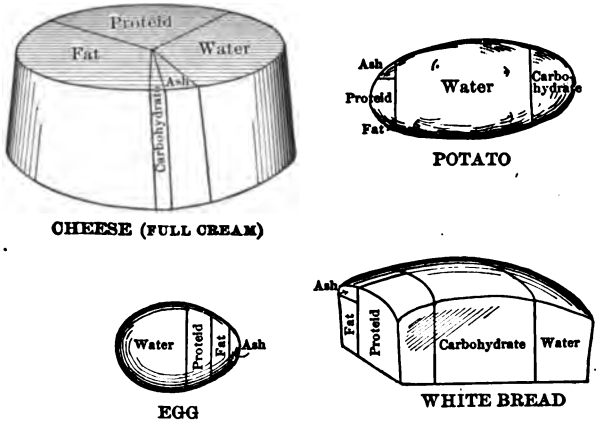



Fig. 6. — Relative proportions of different nutrients in well-known foods

## Dietaries: Foods and the Values of Nutrients in the Body

**Reason for Studying Dietaries.** — Much human welfare depends upon a knowledge of the composition of our foods and the values of the nutrients in the body, and much misery is due to ignorance of the facts. In cold weather and cold countries more fat is eaten. In warm weather and in tropical countries more fruit and nuts are used for food. If you are lean, the doctor may advise more sweet and starchy food. These facts mean that there is a connection between the needs of the body and the food we should eat. Not only may a one-nutrient diet be unhealthful on account of the lack of other necessary nutrients, but the whole food,

*e.g.* whole rice, may contain some substance necessary to good health.

**How Food Values are Determined.** — To select our food intelligently we should know the value of each nutrient in the body. Its value is estimated largely by the heat and strength that it can give the tissues when consumed, or burned, by combining with oxygen in the body. The burning or consumption of coal or wood is merely the combining of the carbon in the coal or wood with the oxygen of the air. During this process, called oxidation (burning), a great deal of heat is given off, and heat is one kind of energy. So in the body, when oxygen unites with nutrients, energy is given to the living matter, resulting in activity and finally in heat. Both of these, heat and activity, may be measured by the total heat given off from the body.

The way in which this was found out is very interesting. At first the experimenters put animals into roomy, well-ventilated metal chambers, surrounded by water. The water would take up or absorb all the heat given out from the resting animal, and could be measured by thermometers. Such an apparatus is called a *calorimeter*, from the words *calor* meaning heat, and *meter*, a measurer. In Europe experiments of this kind were made as early as 1779. In this country Professor Atwater invented and constructed the most elaborate calorimeter. Besides room for a man, it had a folding bed, table, chair, and a tread machine with which the work done by the man inside could be measured. Now when we remember that the heat and muscular activity of the man in the calorimeter all came from the food he had eaten, we might wonder whether the food (nutrients) if it were burned outside the body, but also in a calorimeter, would give off anywhere near the same amount of heat as when consumed in the body. Naturally the investigators thought of this and tried it, and found that the amount of heat given off was the same in both cases. Now a thermometer measures only the degree of heat, no matter how much or how little water there is. The large amount of water surrounding the inner chamber that the man was in required

much more heat to raise it one degree than did the amount of water around the calorimeter in which the food was burned. The degree of heat multiplied by the grams of water would give the rule or standard. So a standard unit, called a *calorie*, is used by all investigators in this line. A *small calorie* is the amount of heat absorbed by one gram of water to make it one degree Centigrade warmer than it was. A *large calorie* differs only in being 1000 times larger, *i.e.* 1000 grams (1 Kilogram). The amount of a food (dried) needed to be burned to raise 1000 grams of water one degree Centigrade is equal to a large *calorie*. This equivalent for protein is about one-fourth of a gram, for carbohydrate the same, and for fat it takes less than one-ninth gram for a calorie. This is because fats give off so much heat when burned. Repeating what was said above by an example from an experiment:[1] A man in a calorimeter, in one day, took in food, protein, fat, carbohydrates, to 5459 calories.

| | |
|---|---|
| He did work on the tread machine equal to . . . . | 602 Cal. |
| The heat given off by the body measured . . . . | 4833 Cal. |
| | 5435 Cal. |
| Experimental error . . . . . . . . . . . . . | 24 |
| | 5459 Cal. |

The following table shows the heat units (Calories) in one serving of some common foods. From 2200 Calories at 14 years to 3400 Calories for adults per day are needed. Each student should make a table of his own meals for a day. To do this he should select the foods from the table that are most like those of his meals; add the Calories of protein, carbohydrate, and fat, apportioning about 500 Calories for breakfast, 600 for lunch or supper, and 1100 for dinner. Do your meals form a well-balanced ration? If not, what nutrients should you increase? What decrease? Would such meals do for an adult at hard work? Make out a dietary of 4000 Calories for a hard-working man, increasing the protein a little and the carbohydrates a great deal.

[1] Howell's *A Text-Book of Physiology*, 1912.

## TABLE SHOWING HEAT UNITS (CALORIES) IN ONE HELPING OF SOME COMMON FOODS[1]

| Proportion Needed Per Day | | 15 % Protein | 60 % Carbohydrates | 25 % Fat | Total |
|---|---|---|---|---|---|
| Food | Amount | Cal. | Cal. | Cal. | Cal. |
| Apple | 4 oz. | 2 | 60 | 4 | 66 |
| Bacon | ⅔ oz. | 7 | — | 105 | 112 |
| Beans (baked) | 3 oz. | 23 | 70 | 20.4 | 113.4 |
| Beef (dried) | ⅚ oz. | 25 | — | 14.5+ | 39.5+ |
| Beef (hind quarter) | 3 oz. | 120 | — | .80 | 200 |
| Bread | 1 slice | 10 | 62 | 5 | 77 |
| Butter | ½ oz. | .6 | — | 107 | 107.6 |
| Cabbage | 2⅔ oz. | 4.8+ | 17 | 2 | 23.8+ |
| Cheese (cottage) | 2 oz. | 38 | 8 | 4 | 50 |
| Chicken (canned) | 1 oz. | 24 | — | 76 | 100 |
| Cocoa | 1 cup | 8 | 15 | 26 | 49 |
| Codfish (dry) | 1 oz. | 28.8+ | — | .1 | 28.9+ |
| Coffee | 1 cup | — | — | — | — |
| Corn flakes | 1 oz. | 12 | 90 | 2 | 104 |
| Corn meal | 1 oz. | 10.4+ | 85.7+ | 4.8+ | 100.9+ |
| Cream | 1 oz. | 12 | 3.3 | 86 | 101.5 |
| Custard (milk) | 4 oz. | 20 | 13 | 50 | 83 |
| Egg | 2 oz. | 30 | — | 47 | 77 |
| Grapes | 1 cluster | 2 | 32 | 7 | 41 |
| Milk | 5 oz. | 20 | 29 | 32 | 81 |
| Mutton | 3 oz. | 80 | — | 120 | 200 |
| Oatmeal | 4 oz. | 12 | 48 | 4.6 | 64.6 |
| Half orange | 4 oz. | 3.3 | 52.5 | .3 | 56.1 |
| Peanuts | 10 nuts | 15 | 13 | 50 | 78 |
| Peas (green) | 3 oz. | 18 | 70 | 4 | 92 |
| Pork (chop) | 2 oz. | 35 | — | 164 | 199 |
| Potato | 3 oz. | 10 | 80 | .8 | 90.8 |
| Rice | 1 oz. | 9.1+ | 89.8+ | .1 | 99.0+ |
| Shredded biscuit | 1 piece | 10 | 62 | 5 | 77 |
| Spinach | 1 oz. | 2.3 | 3.6 | .1 | 6.0+ |
| Sugar | 1 oz. | — | 113.6+ | — | 113.6+ |
| Turnips | 2⅔ oz. | 4.8+ | 17 | 2 | 23.8+ |

[1] Compiled from various sources, all of which, in turn, were based on Professor Atwater's or Professor Fisher's work.

**Dangers through Food.** — Here our taste is only a partial guide. We often dislike harmless things. Though often the things that we do like are not best for us, again we can become used to eating things that we do not like but which are good to include in our diet. Spoiled food is offensive to us and in such cases dislike is a good guide, but we should be sure that our senses of taste and smell are well trained. Food may be spoiled in three ways: (1) by fermentation or decay, (2) by the growth of molds and germs, and (3) by the presence of parasites that may continue to thrive in the human body. In the first case our senses are a sufficient guard, providing that the food has not been treated with preservatives.

Those who argue that it is better to have a little unwholesome preservative than the danger of ptomaine poisoning open the way for dishonest dealers to "doctor" spoiled food.

Fresh beef and pork may contain the young of tapeworms and should therefore not be eaten raw. Pork may also contain trichinæ, tiny threadworms that cause trichinosis, often producing death. The proper safeguard is never to eat raw meat. Unsmoked, raw sausages are not a safe food.

Both milk and water are sometimes sources of danger, as they may carry germs. Typhoid fever, consumption, and cholera germs are most commonly carried in this way. In this country, only seaport towns are in any danger from imported cholera.

The other nutrients, starch and sugar, are seldom spoiled or dangerously adulterated. Cheap sugar, and such dried fruits as figs, raisins, and prunes, may contain sugar mites. Though these are not dangerous, they are unwholesome.

Food in tin cans is unsafe when the ends of the cans bulge out, as this is said to indicate that the can is partly filled with gases, arising from spoiled contents.

**The Care of Foods.** — Tin cans should be emptied as soon as they are opened, as poisonous compounds may be formed by the food juices in contact with the metal when

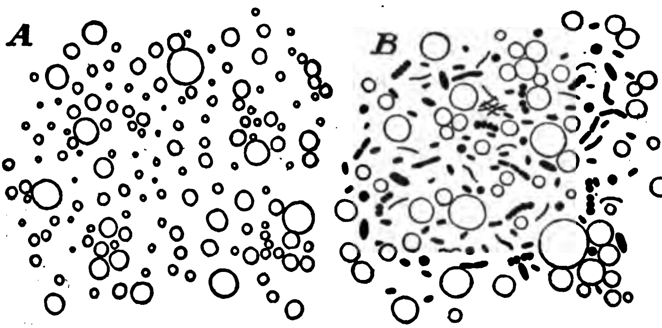



Fig. 7.—*A*, Clean milk shows few bacteria; *B*, Dirty milk, containing many bacteria

exposed to the air. Meat should be kept in a cool, clean place where no animals can touch it, as they may leave parasites on it. If it cannot be kept in a refrigerator, buy only so much as can be used before it spoils; boil or salt it, even temporarily, to prevent the formation of germs of decay. As soon as meat begins to have an odor, it contains germs of decay that are developing poisons called *ptomaines*. Boiling will kill the germs, but it will not remove the ptomaines.

Milk should never be bought or sold at retail from large cans. This custom is forbidden in all large cities, but is still practiced in smaller towns and in villages. Milk should be bought only in closed bottles put up in a sanatory way. The bottles should be kept unopened and in a cool place until the milk is used. The whole top of the bottle should

be washed before opening. This is to remove any germs that may have been left by stray cats and dogs licking the

Fig. 8. — A sanitary bottling room. Here milk is kept pure by absolutely clean handling. Notice the costumes of the men. (From Hoag)

bottles, or by the handling of employees. (For reading refer to Appendix.)

### QUESTIONS FOR REVIEW

1. What is the significance of hunger?
2. For what purposes do we need food?
3. What is a food? How does a foodstuff, or nutrient, differ from a food?
4. What is meant by carbohydrate food?
5. What are three common sources of carbohydrates?
6. Why do we place grains under carbohydrates?
7. What are protein nutrients?
8. What foods are sources of our proteins?
9. What chemical element is characteristic of protein?
10. What are the nutrients in vegetables?

11. Which of these make them especially valuable in scurvy?
12. How are fruits useful in our diet?
13. What is their chief nutrient?
14. From what sources do we get fats?
15. Why are fats good heat-producing foods (chemical)?
16. What are two chief dangers in drinking water?
17. Which danger can be removed by boiling; which one can not?
18. Why not drink from public cups?
19. What drinks are nutritious; which the opposite?
20. Of what use are condiments; desserts?
21. What is the general benefit of cooking food?
22. How may frying food lessen its digestibility?
23. Why is a mixed diet superior to a one-food diet?
24. What does the term "vegetarian" ordinarily mean?
25. What is the proper proportion of nutrients in a day's ration?
26. How is the calorimeter used?
27. What uses can be made of the table of foods showing value in calories?
28. What dangers may we avoid in our foods?
29. What diseases may milk carry?
30. How may milk be made safe?

### EXERCISES

NOTE.—The nature and names of common things are frequently confused. Popularly, but incorrectly, the name "acid" is applied to various drugs or unknown chemicals. Acids and alkalis are frequently used in the following exercises, which are given here to teach something about their nature.

*Tests for Acids and Alkalis.* — 1. (*a*) To learn a way of detecting acids: Some dilute acid, such as nitric acid or vinegar, is poured into a white dish. Pieces of litmus paper, first blue, then pink, are dropped into the acid. The resulting color is then noted. Only true acids give this result. (*b*) To find out which of certain substances prepared for testing are acids, each "unknown" is put in place of the acid and tested with litmus paper. What is the result; the conclusion?

2. (*a*) To learn a way of detecting alkalis: Into a clean dish some alkali (dilute ammonia) is poured. Litmus paper, first pink, then

blue, is dropped into the alkali. What is the result of the experiment? Only true alkalies give the same reaction. (*b*) Test also as "unknowns" such common substances as washing soda solution, lime-water, baking soda in water, the juice of a sour apple, or lemon juice, etc. What are the results and conclusions?

NOTE.—In all foods there are, besides water and salts, one or more substances each of which may be told (tested) by adding certain chemicals. The test chemicals are called "reagents." There are four of these food substances, called nutrients — starch, sugar, fat, protein. To learn if any of these nutrients are present in common foods we must learn to tell each nutrient by a test that no other substance except that nutrient will give.

*Tests for Nutrients.* — 1. (*a*) To learn a test for starch: A small piece of known starch is placed in a white dish and a few drops of reddish yellow iodine solution are added to the starch. What is the resulting color? Break the piece of starch to see the paler shades where less iodine penetrated. Boiling the foods makes the result more certain. Only starch gives this color reaction. (*b*) To learn in which of the substances commonly used for food there is starch, test in the same way as in (*a*) crushed wheat and corn kernels, a bit of scraped potato, banana, apple, onion, and other things. Use the words *much*, *little*, *no* starch in reporting your conclusions.

2. To learn to tell in what foods there is grape sugar: (*a*) Preliminary. A few granules of grape sugar (glucose) in a test tube are covered with a medicine dropper full of strong caustic soda solution, then a *few* drops of saturated solution of copper sulphate are added, and the whole is mixed by shaking. The mixture is then brought to boil over a flame, watching carefully for any change in color. Just as soon as the mixture begins to turn yellow, boiling should cease, otherwise the correct color test, orange, will be passed over. Almost a brick-red is also obtained. What have you learned in this exercise? (*b*) Potato, raisins, banana, sour apple, or lemon, and any of the grains used for food may now be tested for grape sugar, then the results and conclusions tabulated.

NOTE. — The student should remember that these colors are obtained with pure, known nutrients, and that in mixture with other substances he cannot expect to get such clear results. All kinds of grape sugar and some others give the above result.

3. To learn how to recognize fat in foods: (*a*) On a piece of glazed paper, 6 or 8 inches square, six circles are marked off. Within the circles are then placed some known fat, ground buckwheat, flax-seed meal, chopped potato, corn meal, leaving the sixth vacant for chloroform alone. With a medicine dropper as much choloroform is dropped on each circle as will stay in its boundary. Each circle is now labeled, the substances are shaken off, and the paper held toward the light to see results. What does the fat leave. What proof that this could not have come from the chloroform. Tell in each of the other cases, which leaves more, or less, of the appearance left by fat. Which one leaves only a stain? Now tell (*a*) the test for fat, (*b*) the conclusion for each food.

4. To learn how to tell where there is protein: (*a*) A few drops of nitric acid are poured on a little known protein (white of egg) in a test tube and the mixture gently heated to boiling — no more. This is then cooled by setting the test tube in water. (*Caution* — Strong acids and alkalies, mixed while hot, unite with explosive violence.) When cool to the touch, ammonia is added until the mixture is alkaline. Apply the method you have learned in testing for alkalies. As soon as the solution is alkaline, a bright color appears — what is it? If no other substances except protein give this color with these reagents, what have you learned in this exercise?

Apply what you have learned (*b*) to find if there is any protein in the following: crushed peas, crushed beans, cheese, and bread. Compare pure starch and whole wheat. Record results and conclusions as before for the *b*-part of the exercises.

5. Milk is tested to see what nutrients are present: It is better to test for starch and sugar first, waiting for the fat test until the next lesson, as the cream collected on the surface for proportion of cream may be used.

NOTE. — Although the sugar in milk (milk sugar, lactose) gives the test color for glucose, it is not the same; it is an exception referred to in the sugar test, *q.v.*

## CHAPTER III

### THE DIGESTIVE SYSTEM

**Introductory.** — Many animals, such as birds, reptiles, frogs, and fishes, swallow their food whole, while others chew their food more or less thoroughly before swallowing it. This is the case with most mammals and man. Cows, sheep, and others of their kind,[1] though having good teeth, first gulp hurriedly, and while resting regurgitate and re-chew their food thoroughly, swallowing it again.

**Teeth in General.** — In consequence the teeth are better developed for chewing, *i.e.* grinding and refining the food, in the higher than in the lower animals.[2] In frogs, snakes, and fishes the teeth are merely for holding their prey or food from slipping away, or for helping to work it down the food tube. Birds have no teeth, so the food, swallowed whole, is softened in the crop, which is located in front of the breast, the work of the missing teeth being done by the grinding action of gravel in the gizzard of birds. Poultry raisers say, "fowls' teeth," when they give their flocks gravel.[3]

### THE ALIMENTARY OR FOOD TUBE

**The Mouth and Mastication.** — In studying the mouth and contained organs, the student should not content him-

[1] Ruminants.

[2] Historically, teeth originated outside the mouth, as now seen on the head of some of the lower fishes.

[3] While all modern birds have no teeth, the ancestral birds had many.

self with mere reading, but should carefully examine his own mouth cavity by means of a hand glass. We are apt to think of the mouth as a cavity of considerable size, as indeed it is when fully opened; but we are not so likely to

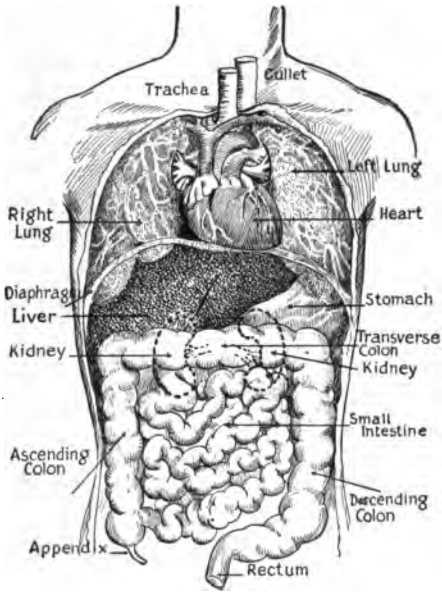



Fig. 9.—Internal organs of the body in position

Based on a student drawing. It is intended for practice, to copy until familiar with the position of all organs

think how completely the cavity is obliterated when the mouth is closed. If one notes the sensations from the mouth when it is closed, he will perceive that the tongue almost entirely fills the space, touching the roof of the mouth, and the teeth in front and at the sides. (See Figs. 10, 17, and 18.)

While food is being chewed, it is mixed with watery

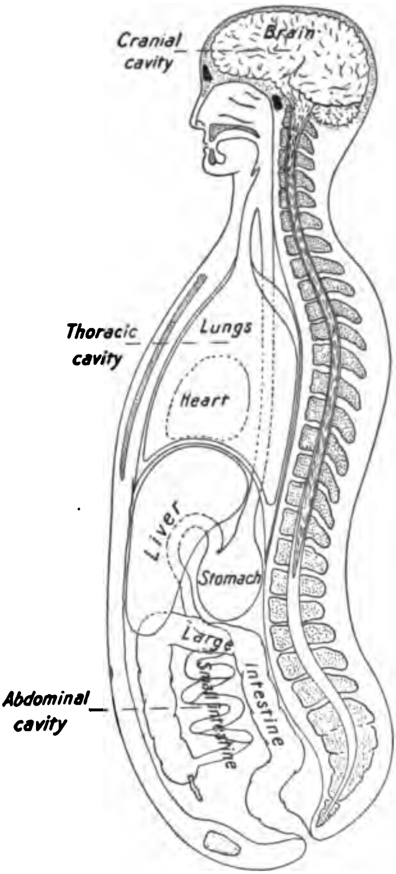



Fig. 10.—Diagram showing the location of the principal organs

mucus[1] and saliva, thus moistening it thoroughly. This is the only use of mucus, but the saliva, as we shall see, has a dissolving and digesting action on the food. The lips, cheeks, and especially the tongue, help the chewing of the food more thoroughly by repeatedly thrusting it back between the teeth. If one will make all the chewing motions he can with the tongue, teeth, and cheeks, finishing by scraping or rubbing the inside of the mouth with the teeth and tongue, as one does in finishing a mouthful or a meal, he will understand better this most important step in digestion; *i.e.* mastication.

**The Hygiene of Mastication.** — An illustrious English statesman is said to have attributed his vigorous health

[1] All the cavities and passages in the body to which the air has access, such as the digestive and respiratory passages, are lined by mucous membrane.

largely to the habit of chewing each bite of food many times before swallowing it. The doctors hold that "well-chewed food is half digested." Not infrequently they recommend "chewing" the soup we eat and the milk we drink. A little practice will show what they mean and will improve the digestion. Milk should not be taken ice-cold nor in large gulps, but should be sipped.

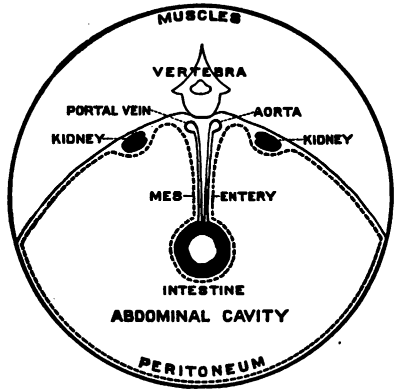


Fig. 11.—Cross-section view through body

Thorough mastication helps digestion in three ways: 1. It helps or induces the flow of digestive juices; 2. It increases the flow of blood to the digestive organs; 3. It makes the work of the stomach easier.

**The Tongue.** — The tongue consists chiefly of muscles, extending in different directions, thus giving it a variety of motions. The tongue is the chief organ of taste, and is therefore (with the sense of smell) the gatekeeper of the digestive tube. The tongue has also a keen sense of touch (the keenest of any part of the body), and so is useful in detecting and removing any food particles that may remain on the teeth after a meal. During mastication the tongue, the lips, and the cheeks keep the food between the teeth. When the morsel of food is sufficiently masticated, the tongue pushes it back into the pharynx to be swallowed.

## The Teeth

**The Kinds of Teeth and their Arrangement.** — Beginning at the middle of the front of the mouth, there are (in

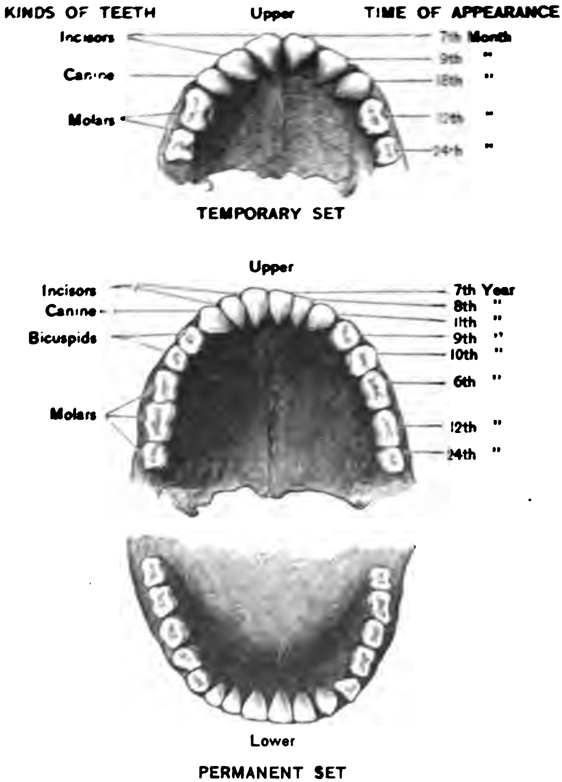



Fig. 12. — Teeth: Kinds, arrangements, and times of appearance

the normal adult) eight teeth in each half jaw: two incisors (chisel-shape), one canine (pointed), two bicuspids (or premolars), and three molars.

**External Features of a Tooth.** — Examine one of the front teeth. It has the following parts: —

1. The crown, the part that is above the gum.
2. The root, the part that was buried beneath the gum.
3. The neck, a more or less constricted part, dividing the crown from the root; it is normally at about the surface of the gum.
4. A hole at the tip of the root.

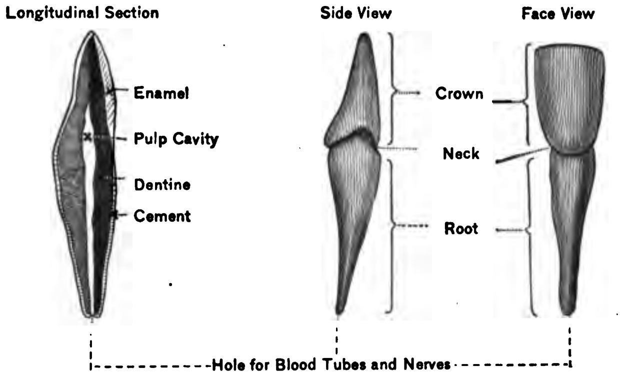



Fig. 13. — Parts of a Tooth. (Incisor.)

**Structure of a Tooth.** — 1. The pulp cavity, communicating with a hole in the tip of the root, through which the nerve and blood tube enter.

2. The mass of the tooth is made up of a substance called dentine (ivory).

3. The crown of the tooth has a covering of enamel, a very hard substance.

4. The root is covered with a bony substance called cement.

**The Milk Teeth.** — The thirty-two teeth of the permanent set are preceded by a temporary set of twenty milk

teeth. Because the first set is temporary it should not therefore be neglected. Cavities in these should be filled and the teeth kept clean. Before the temporary set has gone the first of the permanent set appear. The first of these, often called the "six-year molars," are just back of the hindermost "milk molars." These should receive especial care, as they will never be replaced. Any beginning of decay in them ought to receive prompt attention.

**The Hygiene of the Teeth.** — The teeth need careful attention. They should be thoroughly brushed twice a

Fig. 14. — Plaster casts of crooked teeth caused by adenoids

day, on rising and on going to bed, or after each meal. If a tooth paste, recommended by a reliable dentist, is not used, a good white castile soap will serve well. It is better to use tepid water. If the teeth are not thoroughly cleansed, the particles of food which remain will soon begin to decay. This decay is caused by the growth of germs, usually some kind of bacteria, and the decay thus begun is likely to develop acids which attack the bony material of which the teeth are composed. Sweet substances are very likely to decompose and form acids; so we must clean the teeth after eating sweets. Toothpicks are useful in removing the larger particles, but only wood or quill toothpicks should be used,

in order not to dislodge fillings. The teeth should be examined once a year by a dentist, and any cavities promptly filled.

### The Saliva

**The Digestive Action of Saliva.** — After mastication the next important step in the process of digestion is the action of saliva on starchy food. This may be determined in a rough way by chewing for some time light-baked cracker, or bread. The taste changes from a starchy to a sweet taste. This change does not take place in protein or fat. One would naturally suppose that the sweet taste is due to sugar. This is true, and means that the saliva has somehow changed the starchy food to sugar. The insoluble starch has been changed into sugar that will dissolve in the water of the saliva. The starchy food is thus partly digested.

**Digestive Liquids and Ferments.** — The dissolving or digesting action of saliva has been found to be due to a special substance in the saliva, called *ptyalin*. The saliva is called the digestive juice or digestive liquid, and the ptyalin, the special substance in the juice, is called the *ferment*. Let us now consider the ferments as they occur in each of the digestive liquids.

**Ferments or Enzymes.** — Ferment, or *enzyme*, is merely the name of the special substance in each digestive liquid which changes an indigestible nutrient, as ptyalin did the starch, to a soluble or digested product, *e.g.* sugar. The ferment itself does not change. Ferments occur elsewhere in nature, but behave in the same way, *i.e.* they change one substance into another, where this can be done. A small quantity, therefore, is able to continue its action on a

large amount of material to be changed, as is the case when sweet liquids ferment to alcohol by the action of yeast.

NOTE. — Formerly the yeast plant itself was supposed to be the ferment, and was called an organized ferment, because, being a plant, it is an organism. It is now held that the yeast plant gives out, or secretes, a ferment which changes the sugar to alcohol, and so the ferment is, after all, a special chemical substance — similar to ptyalin — and not organized.

**The Source of Saliva.** — We are so accustomed to the liquid, composed of mucus and saliva, collecting in the mouth and swallowed from time to time, that we may not have thought to ask where it comes from. As it is only one of many liquid substances that the body forms in special organs called glands, it may be well to learn about the general nature of glands as illustrated by those that form the saliva.

**The Secretion of Saliva.** — We are familiar with the fact that the skin secretes perspiration or sweat, as if it were a huge gland covering the body. The real glands that give out the beads of perspiration are minute bags lined with cells that secrete the sweat in the interior, and this then comes to the surface through tubes called ducts. In the same way the saliva is poured into the mouth from ducts, the openings of which may be seen under the tongue, or better, in the cheek opposite the second molar, when the mouth is examined with a mirror. (See Figs. 15 and 16.) The salivary glands are composed of many branching sacs, lined with cells and opening into one common duct. These secreting cells take the material from the surrounding blood tubes and make saliva out of it.

**The Hygiene of Salivation.** — When we see or smell something good to eat, we say, " it makes the mouth water."

Why does this occur? Because the flavor developed by cooking, or due to proper seasoning, as also foods especially palatable, increase the flow of saliva and so help in digestion.

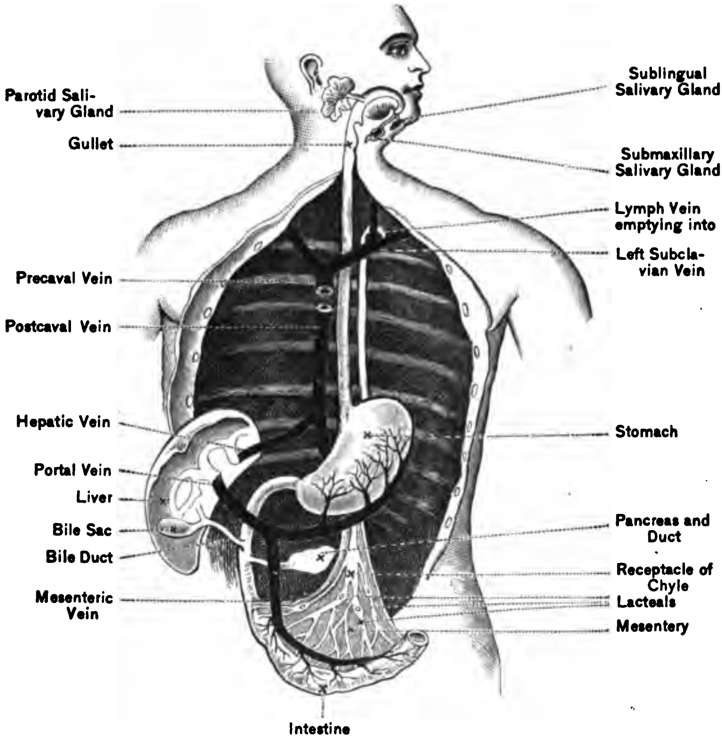



Fig. 15.—Diagram of the organs concerned in the conversion of food into blood

When one is embarrassed or frightened, the mouth often feels dry. How would fear, embarrassment, or unpleasant thoughts affect the flow of saliva and so interfere with digestion? To be sure, thoughts, emotions, sight, taste, and smell can only indirectly change the flow of saliva

through nerves, since they cannot affect the glands except through nerves. This is true of glands in general. They are doubly dependent on nerve control: 1. Nerves control the blood supply to the gland. 2. They control the time and amount of secretion of the cells themselves.

**The Amount of Saliva Daily.** — The amount of saliva secreted daily is estimated at three pints. Of course the glands should be allowed to rest between meals. The

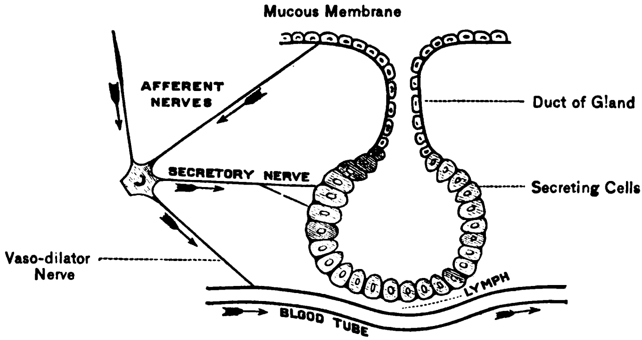



Fig. 16. — Diagram of a salivary gland. (After Landois and Stirling.)

habit of chewing gum *incessantly*, though claimed to aid digestion, undoubtedly does harm. During the resting period the glands accumulate material for the active work of secretion, for there is no sac in which to store the saliva, and it must be made as fast as it is needed.

**The Essentials of Glands.** — 1. *Cells lining a cavity*, the cells having the power of taking something from the blood (or lymph).

2. *Blood supply* or lymph supply.

3. A *duct* or tube to pour out on some surface the liquid taken from the lymph. (Single-celled glands have none.)

4. *Nerves* to the cells by which their action is controlled.

5. Special nerve centers controlling the various glands. The cells of the glands in many cases so alter the substances taken from the blood that what is produced by the gland differs from anything found in the blood. The gland may be said to manufacture the liquid.

**Swallowing or Deglutition.** — After the food has been thoroughly masticated it is swallowed by pushing it back with the base of the tongue into the next division of the

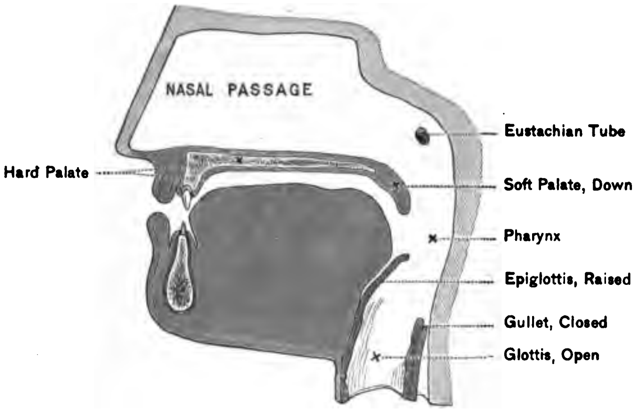



Fig. 17. — Diagram showing the positions of the organs of the mouth and throat during breathing

digestive tube — the *pharynx*. (See Figs. 17 and 18.) This is the only part of the food tube that is also used for the passage of air in breathing. With a mirror one can see that it is a funnel-shaped cavity, communicating above with the passages from the nostrils. The soft palate hangs down into this cavity, and as food is swallowed the palate is pushed back and up, to close the passages from the nostrils. At the same time a stiffer, but otherwise similar, valve — the *epiglottis* — at the base of the tongue closes the air tube while food passes into the next division

of the food tube, the *esophagus* or gullet. (See Figs. 15 and 18.) This is narrower than the pharynx, and its walls are strengthened by circular muscle fibers which constrict the gullet just above the mouthful of food being swal-

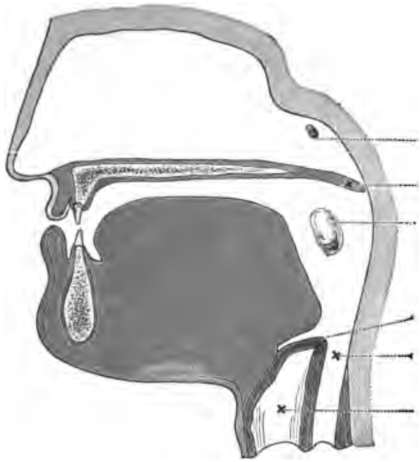



Fig. 18. — Diagram showing the positions of the organs of the mouth and throat during swallowing

lowed, thus pushing it down. A sort of contraction wave follows the food bolus, pushing it on until it is in the stomach.

NOTE. — It is a popular mistaken idea that liquids "run down the throat" when we are swallowing them. Each swallow of a liquid is pushed down and can go no faster than the muscular contraction wave above mentioned. When a horse or cow drinks from a pail on the ground, the water is forced upward in this way. This is the explanation of the juggler's trick of drinking from a glass of water on the floor while he reaches it bending down over a chair.

**Digestion in the Stomach.** — The swallowed food collects in the stomach, a reservoir-like, enlarged portion of

the digestive tube below the floor of the chest cavity.[1] In Figs. 9 and 10 the normal position of the stomach is shown a little to the left of the slanting edges of the ribs, below the breastbone and just below the place where one can feel the heartbeat.

NOTE. — It is important in examining such figures in the book always to notice whether the figure represents the body turned toward you, for then right and left are the opposite of your own body.

### NORMAL CONDITION OF THE STOMACH — HYGIENE

Before food enters it, the stomach is shrunken and pale, and in some places its walls touch inside; but as food enters, it enlarges until it may become about one half the size of the head. One should never eat so much food as to distend the stomach too far. Excessive drinking causes abnormal distention and hinders digestion. The normal capacity of the stomach of an adult is about three pints. The stomach is said to take on a ruddy or pink appearance as its activity begins. This is caused by the increased flow of blood to the organ, and is necessary for the secretion of a new digestive juice that is now mixed with the food as fast as it enters the stomach. It is a good thing to take soup or some hot drink just before a meal in order to increase the flow of blood to the stomach. Disagreeable topics and worry should be avoided at mealtime, as they tend to keep blood away from the stomach. (See the chapter on Circulation.)

It is said that the gastric juice (from *gaster*, the stomach) begins to flow into the stomach as soon as we begin to

[1] There are many peculiarities of the stomach in the animal kingdom. The one deserving special mention is that of cows, deer, and their kind, which have a four-chambered stomach. A clean calf's stomach can be secured at small cost from any butcher, and will show the wonderful "psalterium" or "manyplies" and the "net."

chew the food. It may be, as some hold, that it begins with, and is reflexly caused by, chewing and the flow of saliva in the mouth. This gastric secretion is also favorably affected by pleasant mental states. The gastric juice is not secreted after sleep comes on or during unconsciousness.

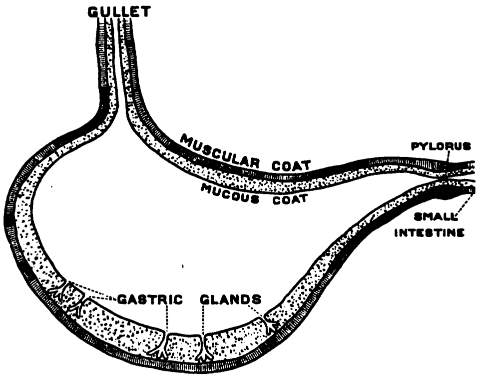



Fig. 19. — Longitudinal section of stomach, showing gastric glands in position.
(Dorsal view. Mucous coat unduly thickened.)

NOTE. — Food introduced into the stomach of an unconscious dog, or one that did not chew the food, is not digested (Cannon). As before indicated, the gastric juice is made from the blood by glands embedded in the thick walls of the stomach. The secretion comes to the inner surface of the stomach in beadlike drops, somewhat like drops of perspiration on the skin. The flow of gastric juice continues throughout the process of digestion, and may amount to three quarts. It is to be understood that the gastric, as well as other digestive, juices are largely water with some mucus, and that there are special ferments in each juice.

**The Work of the Gastric Juice.** — In the gastric juice there are two ferments, *pepsin* and *rennin*.[1] Both of these act on proteins in the presence of an acid, 0.2 per cent

[1] Rennet, used in cheese making, is a familiar substance obtained from the fourth stomach of the calf. When milk enters the stomach, it is curdled; that is, the casein previously dissolved in the liquid milk is coagulated. This curdling, or coagulation, is due to a ferment in the gastric juice called *rennin*. It is thought to be similar to pepsin. The pepsin sold at drug stores is extracted from the lining of the pig's stomach.

being normally present. Thus we see that the gastric juice is acid, while the saliva is alkaline. Sometimes the gastric juice becomes too acid, making the so-called " sour stomach," which is relieved by a little powdered charcoal or baking soda. The pepsin converts the protein into a soluble substance, called *peptone*, which can be absorbed into the blood through the walls of the small intestine.

Experiments have shown that proteins are digested in the stomach, but starch and fats are not.

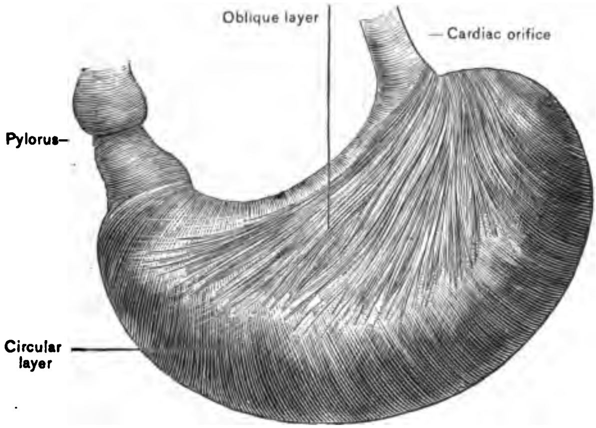



Fig. 19 A.—Muscles of the stomach (From Morris' *Human Anatomy*). The layer of longitudinal fibers removed

**Churning Action of the Stomach.** — During this time all the food is soaked by the gastric juice, the process being greatly assisted by the churning motion of the stomach caused by the action of the muscular coat. If one should slowly contort his mouth in all possible directions by the muscles in cheeks and lips, it would give some notion of the movements of the stomach. The food is thus gradually reduced to a pulpy mass called *chyme*.

During the first part of digestion in the stomach the thick ring of circular fibers called the *pylorus* (gatekeeper), around the opening of the stomach into the intestine, keeps the passage nearly closed, leaving a small orifice for liquids only. But as the food is reduced to the proper condition the pyloric muscles relax and allow the chyme to pass into the intestine. And at last any indigestible substances are usually allowed to pass.

**Time of Stomach Digestion.** — The time required for the digestion of any ordinary meal is from three to four hours, though this may be much longer if very indigestible substances have been eaten, or if the condition of the body or mind is such as to retard the process of digestion.

**Chyme.** — The whole mass, now called *chyme*, is passed on into the small intestine. It is *acid*, and in a liquid or semi-liquid condition. Chyme as it enters the intestine is a mixture of digested, partly digested, and undigested materials. Some of the starch has been changed to glucose, but only a small part, owing to the short time of mastication. The bulk of the starch is unchanged. Some of the protein is already changed to peptone. Part is still protein, while part is in an intermediate stage between protein and peptone. Fat is essentially unchanged, but is melted by the heat of the mouth and stomach, and is more or less divided into small drops by mastication and the movements of the stomach. For instance, in eating bread and butter, the melting butter will be finely mixed with the bread as it is chewed. The water in the chyme was partly taken in drinking, and partly derived from the saliva and gastric juice. There are also present ptyalin, pepsin, mucus, salts, and some indigestible substances. At intervals the sphincter muscles of the pylorus relax, and the

contractions of the stomach send the liquid mixture into the intestines by spurts.

**Work of the Intestine.** — The small intestine has essentially the same structure as the parts of the digestive tube already studied; namely, a mucous lining beset with an immense number of tubular glands, called intestinal glands. These secrete a liquid collectively called the *intestinal juice*, whose exact work is not well known, but which may be said to complete the work of the other secretions. The intestine has also a muscular coat with circular and longitudinal fibers. And the muscular coat does the same work of mixing the juices with the food and of moving it along (peristalsis).

**Bile and Pancreatic Juice.** — Soon after the chyme enters the small intestine it has poured upon it two liquids, which enter the intestine in one common stream; these are the *bile* and the *pancreatic juice*, both strongly alkaline. These juices come from two large compound glands, the liver and pancreas.

**The Work of the Pancreatic Juice.** — The pancreatic juice acts on all the digestible nutrients: —

1. A ferment in it called *amylopsin* acts on starches, changing them to sugar, even more energetically than the ptyalin of the saliva.

2. Another constituent of pancreatic juice is *trypsin;* like the pepsin of gastric juice, this ferment has the power of changing proteins to peptones.

3. The pancreatic juice also acts on the fats in two ways: —

(*a*) It emulsifies them by its *alkali*, *i.e.* the fat is divided into exceedingly fine drops, each enveloped in a coating of albuminous substance. An emulsion can be made arti-

ficially by shaking together water, oil, and white of egg. The shaking breaks the oil into fine drops, which would soon gather again if no other substance were present; but it is supposed that the albumen forms a thin coating around each droplet, enabling it to remain distinct in the liquid.

(*b*) The fats are also acted on by *steapsin* (lipase), another ferment of the pancreatic juice; it decomposes them, and thus more fully prepares them to be absorbed.

**Functions of Bile.** — The bile is secreted all the time, but more actively during digestion. The bile made while digestion is not going on is stored in the bile sac. The functions of the bile are still poorly understood. But the following are believed to be a part of its work: —

1. It is believed to aid in emulsifying the fats.
2. It is supposed to aid in the absorption of fat.
3. The bile, to a large extent, is waste matter; so the liver is an organ of excretion as well as an organ of secretion.

**Action of the Intestinal Juice.** — The intestinal juice contains a ferment, called *invertin*, which changes cane sugar to dextrose, a variety of grape sugar.

**Review of Digestive Liquids.** — Saliva acts only on starch, gastric juice on proteins, bile on fats, whereas pancreatic juice acts on all three, and, probably, more energetically than the above-named liquids.

### QUESTIONS FOR REVIEW

1. Do all animals chew their food?
2. What use of their teeth do some lower animals make?
3. What higher animals have no teeth? How is their food refined?
4. What part do cheeks and tongue take in masticating food?
5. What are the principal groups of permanent teeth?
6. What are the three regions of a tooth?

7. What is the anatomy of a tooth?
8. How are we to care for our teeth?
9. How does saliva digest food? What ferment? What nutrient?
10. What are enzymes? What peculiar properties have ferments?
11. What are the essentials of salivary glands?
12. How is swallowing food explained, as shown in an animal swallowing with lowered head?
13. What are the two uses of the stomach?
14. How does it differ in appearance when empty from when it has received food?
15. What kind of food is a good preparation for a meal? What kind of drink? Why?
16. What conditions affect the flow of gastric juice?
17. How are proteins affected by pepsin? Which are affected by rennin?
18. How would it do to have a stationary stomach? Why must protein be digested?
19. What is the chyme? What are the ferments in the pancreatic juice?
20. What are the corresponding products? What nutrients are affected?
21. How is fat digested? How does bile help? Is it a digestive juice?
22. Does bile have any ferments? What is the action of invertin in the intestinal juice?

## EXERCISES

NOTE. — We learn that all nutrients in food must be digested in order to be absorbed through the walls of the intestine. It will be of interest to see which ones are easily soluble in water in the form in which they are ordinarily taken as foods. While doing this work, the student must also be sure that he understands what is meant when we speak of anything as soluble. As indicated above, solubility in water is meant. Those foods that are not soluble in water must be acted on chemically by the digestive liquids that change the foods so that they will readily dissolve in the water that is present in the liquids. This is real digestion or "digestion proper."

*Solution in Water.* — For the following exercises several feet of animal intestine, merely rinsed but not cleaned for sausages, may be obtained from the butcher. Any part not to be used at once may be inflated with air, tied in 4-inch sections (sausage-like), and dried. These can be kept in tight bottles, away from insects, for future use. Or the membranes may be kept in a 3 per cent formalin solution.

To find which nutrients are soluble in water, shown by passing through intestinal membrane: —

1. Some grape sugar mixed with water is placed in a section of animal intestine and suspended in pure water. How can you test to see if the sugar has dissolved? After stating the result and conclusion state whether you think sugar could be absorbed through the intestine without further digestion.

2. Starch boiled in water is placed in another section of animal intestine and suspended in pure water for some hours. How can you find out whether the starch is dissolved? After deciding this, tell the result and conclusion. Would starch need digesting before absorption? Why?

3. Boiled white of egg mixed with water is placed in a suspended section of animal intestine. After testing whether any protein has dissolved and passed through the membrane, state your conclusion in answer to a question similar to the last.

4. Oil shaken with water is treated in the same way. How can you test in this case whether any of the oil has passed through the membrane? Would oil need to be digested? How do you tell?

NOTE. — Some kinds of raw protein will pass through wet membranes. We should remember that in the intestine where the food is absorbed there is a moist living membrane, not cured osmotic membrane, such as we use in the above exercises.

*Digestion Proper.* — In the digestive liquids there are ferments which chemically change the nutrients so that they dissolve in water.

1. To learn the action of the *ptyalin* of saliva on starchy food: (*a*) In a test tube are placed some fragments of a light-baked cracker, or white bread, and tested for grape sugar; (*b*) A little saliva is then tested in the same way. What is the result in each case? (*c*) Now some of the same starchy food is chewed, mixing thoroughly with saliva. After testing in the same way as (*a*) what is the result?

What change has taken place in the starchy food that was chewed? What has caused the change? Of what use?

2. To learn how the ferment *pepsin*, in the gastric juice of the stomach, acts on insoluble protein, such as boiled white of egg: Into a small tumbler put one half teaspoonful of scale pepsin, 6 tablespoonfuls of water, and one teaspoonful of hydrochloric acid. Pour from this into three test tubes or bottles and add to one several pieces of hard-boiled white of egg the size of peas; to another add the same amount of *minced* white of egg; to the third add the same amount of minced white of egg and enough baking soda to counteract the acid. This may be told by taste or with litmus paper. If these tubes are kept at the temperature of the body, by setting in a vessel of water at the right temperature for several hours, the results may be seen the same day, otherwise they may be left at room temperature until early the next day, when the results of digestion should show. How does the egg appear in each tube? If the exercise was successful, you should be able to tell whether it is worth while to chew food thoroughly, and what condition of the gastric juice in the stomach is important. The third tube represents the condition in certain forms of dyspepsia — alkaline gastric juice.

3. To learn the action of *rennin*, another ferment in the stomach: About 5 cubic centimeters of fresh milk are placed in a test tube, a little rennin powder (as much as may be held on a penknife point) is added, mixed thoroughly, and warmed over a flame. It is important not to heat the mixture too much. How does the milk change in consistency? What is the common name applied to such milk? Recalling the meaning of "digestion," tell whether rennin digests milk or not.

NOTE. — This is the way milk is treated in making cheese. All raw milk taken into the stomach is first coagulated by rennin before it is acted on by pepsin.

4. To find whether gastric juice or pancreatic juice, which occurs in the small intestine, mixes more readily with fat: Mix a little oil in a test tube with a larger quantity of gastric juice, and the same in another test tube with an equal amount of pancreatic juice.[1] What

[1] The pancreatic juice for exercises 4 and 5 is made similarly to the gastric juice in experiment 2, using pancreatin powder and strong alkali instead of the pepsin and acid.

is the result in appearance? Where would fatty food be more favorably affected, in the stomach or in the small intestine? The milky mixture formed by the pancreatic juice is called an emulsion. Milk is a natural emulsion.

5. To learn the effect of *pancreatic juice* on starch and protein: In one test tube is placed some protein, in another some starch paste; pancreatic juice is added to each. The one with protein is set aside under the same conditions as the one with protein and gastric juice (Ex. 2.) For the effect of the *trypsin* in the pancreatic juice on the protein it is better to wait until the next day, to see whether the protein is dissolved. How can we tell whether the *amylopsin* of the pancreatic juice has digested the starch? Compare with Ex. 1, *c* above. The finest color reaction is obtained after several hours, or the next day.

Now summarize the effect of saliva (ptyalin) and pancreatic juice on starchy food, of gastric and pancreatic juice on protein, then on fatty food.

If it has not previously been done, it will be interesting to compare the fat emulsion by pancreatic juice with the natural emulsion, milk, as seen under the microscope. (See Fig. 4.)

## CHAPTER IV

### GENERAL HYGIENE OF DIGESTION — ABSORPTION

**Conditions Aiding Digestion.** — A prime requisite for a good digestion is a tranquil condition of the whole body, especially of the nervous system. We see that the blood must be massed in the digestive organs at the time of digestion. As there is a limited amount of blood in the body, it is evident that if more is sent to one part, other parts must at the time receive less. If we try to study hard immediately after eating, we are calling the blood away from the organs of digestion, and to that extent interfering with the process of digestion. If we exercise the muscles too vigorously soon after eating, we call the blood to the muscles, and so take it away from the stomach and intestines. If, after prolonged study, one is unable to obtain sleep, it may sometimes be efficacious and very desirable to eat a little of some very simple food for the purpose of drawing off the blood to the stomach, and thus relieving the brain. A little muscular exercise may accomplish the same result, or a footbath may be employed. For many persons it would probably be better to take a simple lunch than to go to bed hungry, although one should be careful not to make this a habit.

It is exceedingly difficult to lay down general rules in regard to diet. To a certain extent each person must be a law unto himself, for what agrees well with one may act almost as a poison to another. Moderation should always

be observed, especially in taking foods to which we are not accustomed.

**Solid Foods Digest Slowly.** — Suppose one were to sit down to eat dinner when ravenously hungry. If in such a condition one begins with solid food, he is likely to eat too fast. Hunger is a demand of the system for food. It takes some time for solid food to go through all the processes of digestion and be absorbed into the system and appease hunger.

**Value of Soup.** — But if a soup be first taken, part of which is readily absorbed, the demand of the system will begin to be met, and there will not be the same tendency to rapid eating. Further, a warm soup stimulates the blood flow in the mucous membrane, and thus prepares for more thorough digestion. It is easier after a soup to masticate the solid portion of a meal deliberately.

Hot drink, whether it be tea or coffee, or simply hot water, is usually beneficial, especially to a weak digestion, when taken before meals.

**Desserts.** — Dessert and sweetmeats, following a meal, are often very helpful by further stimulating the secretion of the glands. Nuts are not very digestible unless they are eaten with salt. The agreeable taste stimulates the digestive glands to increased activity. The same may be said of cheese.

> "Cheese is a surly elf,
> Digesting all things but itself."

The average pie needs some extra help for its digestion. Donoghue, formerly champion long-distance skater, when asked if he dieted in preparation for a race, said he avoided pastry. If the vigorous digestion of a man skating for hours daily in zero weather cannot profitably manage pie,

how in the case of sedentary persons? If pie is eaten, it should be masticated with very great thoroughness. Undoubtedly most persons would be better off if they did not eat puddings and pastries. By some, fruit is preferred before meals, especially before breakfast.

**The Bad Effects of Imperfect Mastication.** — If we swallow food before it is thoroughly ground and mixed with the saliva, the stomach and other parts of the digestive organs will require much more time to reduce the food to a liquid form. Further, when eating hastily, we are very apt to eat too much. Thus we may give the stomach a double amount of material to handle, and the material may not be half so well prepared as it should be. The work thus thrown upon the stomach may easily be made fourfold. Of course the organs suffer, and, sooner or later, if this treatment is continued, indigestion results.

**Desirable Conditions for a Meal.** — Not only mastication, but the whole process of digestion, goes on better when the body and mind are at rest and in a peaceful and contented condition, as not only the salivary glands, but all the glands, are under the control of the nervous system, and are greatly influenced by the condition of the body. During a meal, and for a short time before and after, all thoughts of one's occupation, and especially all anxiety, should be absolutely dismissed from the mind. For those whose digestion is not strong, it is especially desirable to secure a period of rest after each meal, taking a lounge or easy-chair, closing the eyes, and, as nearly as possible, closing the mind; for some, even a short nap is very helpful.

During a meal there should be conversation on topics of general interest. "Chatted food is already half di-

gested." But there is danger of swallowing the food hastily (bolting it) in order to talk or answer.

It is said that the people of the United States are nervous, and eat — as they do almost everything else — hastily. Deliberation in eating adds to dignity as well as health, and properly may be considered an evidence of culture.

**Time of Eating.** — Probably our almost universal custom of three meals a day, resulting from experience, is well adapted to the needs of our people. Theoretically, the chief meal should be near the middle of the day, as is the custom in the country; for the bodily powers are higher than later in the day. But for city people, and others who are very busy in the middle of the day, it is undoubtedly better to take the chief meal after the rush of the day's work is over, when there is time for a deliberate meal and when the mind is free from business cares. For many, too, this is the only time when the whole family can leisurely meet at the table.

Eating between meals — "piece-mealing" — is not a good practice. The stomach should have time to rest and prepare for the work of digesting another meal. Many find two meals a day sufficient. There are some persons, however, for whom it would be better to have more meals, with less food at each meal. Meals should be regular.

**Amount of Food Needed.** — This varies greatly with the individual, age, kind and amount of labor, etc., so that no very helpful rule can be given. Each person must find by experience what is best for himself. It is the opinion of many leading physicians that the majority of mankind eat too much. The fasting enjoined upon some is undoubtedly hygienic; and it would be a valuable lesson for more persons to experiment in the line of fasting.

## Review of Digestion

| Parts of Digestive Tube | Mechanical Processes | Glands | Liquids | Ferments | Chemical Change | Absorption: Material | Absorption: By |
|---|---|---|---|---|---|---|---|
| *Mouth* | Cutting and Grinding | Salivary | Saliva | Ptyalin | Starch to Grape Sugar | Sugar, Water } Traces | |
| *Pharynx* | Raising Soft Palate<br>Depressing Epiglottis | Mucous | Mucus | | | | |
| *Gullet* | Food carried to Stomach | Mucous | Mucus | | | | |
| *Stomach* | Churning and Mixing | Gastric | Gastric Juice | Pepsin<br>Rennin | Protein to Peptone | Water<br>Salts<br>Sugars<br>Peptones | Blood Capillaries |
| *Small Intestine* | Mixing and Moving Food | Liver<br>Pancreas<br>Intestinal | Bile<br>Pancreatic Juice<br>Intestinal Juice | { Amylopsin, Trypsin, Steapsin<br>Invertin | Starch to Grape Sugar<br>Protein to Peptone<br>Fats { Emulsified, Decomposed<br>Cane Sugar to Grape Sugar | Water<br>Salts<br>Sugar<br>Peptone<br>Fats | Blood Capillaries<br>Lacteals |
| *Large Intestine* | Food Forced on<br>Waste expelled | Mucous | Mucus | | | Water | Capillaries |

**Errors of Diet.** — Sir Henry Thompson, one of the foremost authorities in the world on the subject of foods, says: "I have come to the conclusion that more than half of the disease which embitters the middle and latter part of life is due to avoidable errors of diet; and that more mischief, in the form of actual disease, of impaired vigor, and of shortened life, accrues to civilized man from erroneous habits of eating than from the habitual use of alcoholic drink, considerable as I know that evil to be."

## Absorption

**From the Stomach.** — Some parts of the food that are already digested, or substances already dissolved in water, *e.g.*, sugar, peptone, salts, — may be absorbed immediately through the walls of the mouth and stomach into the blood capillaries. Recent experiments show that, contrary to popular belief, the amount of absorption from the stomach is much less than was formerly supposed; water, for instance, "when taken alone, is practically not absorbed at all in the stomach. As soon as water is introduced into the stomach, it begins to pass out into the intestine, being forced out in a series of spurts by the contractions of the stomach."

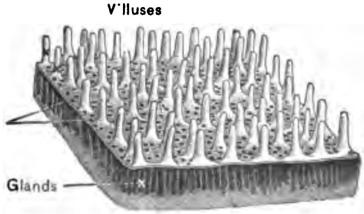


Fig. 20. — Mucous membrane of small intestine

**From the Small Intestine.** — The mucous membrane lining the small intestine is thrown into ridges and folds; unlike those of the stomach, they run transversely. Again, while the folds in the lining of the stomach are temporary,

these are permanent. They serve to increase the surface of the lining, and to retard the passage of the food material, and so to aid the processes of digestion and absorption. (See Fig. 21.)

**Action of the Hair-like Villuses.** — All the surface, folds, and ridges of the mucous membrane of the small intestine

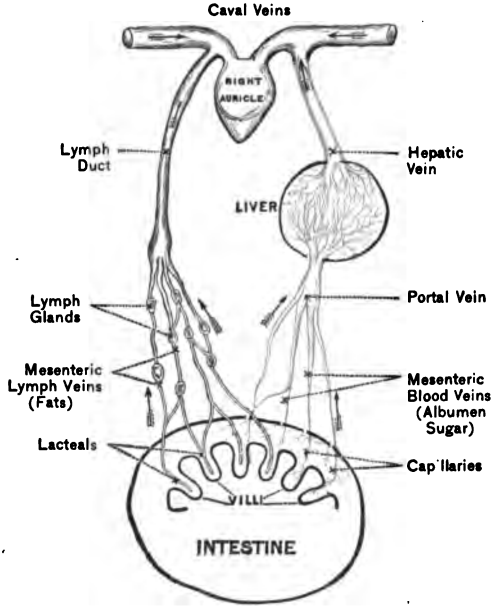



Fig. 21. — Plan of absorption

are thickly set with short, hollow, thread-like projections, like the nap on a Turkish towel. (See Figs. 20 and 22, page 66.) These projections are called villuses (Latin plural, *villi*). The villi very greatly increase the absorbing surface of the small intestine. In each villus is a network of blood capillaries, and the beginning of a lymphatic

capillary called the *lacteal.* (See Figs. 22 and 23. Also see capillaries and lacteals in chapter on Circulation.) Lacteals absorb and lymphatics carry the fatty portions of the

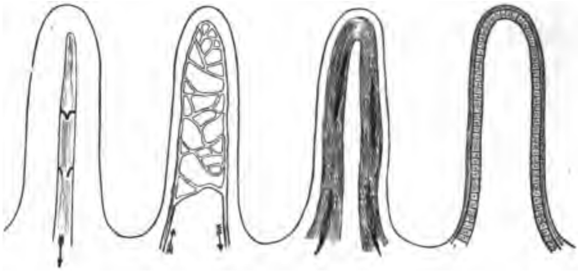



Fig. 22. — Elements entering into the structure of a villus

digested food into the general circulation. Between meals the thoracic duct and the lymphatics of the intestines would hardly be noticed because they are filled with the clear lymph. After absorption of fatty matter they are filled with a white liquid, and are easily seen in a dissection.

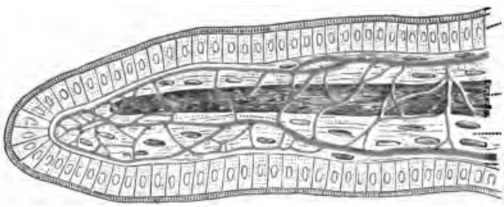



Fig. 23. — Intestinal villus

**Absorption a Vital Process.** — "The processes of osmosis, and to a lesser extent of filtration and imbibition, as they are known to occur outside the body, *were* supposed to account for the absorption of all the soluble products. This belief has now given way, in large part, to newer views, according to which the living epithelial cells take

an active part in absorption, acting under laws peculiar to them as living substances, and different from the laws of diffusion, filtration, etc., established for dead membranes."[1]

**Contraction of the Villi.** — In each villus there are plain longitudinal muscle fibers. When these shorten the villi, they squeeze the chyle that has already been absorbed into the lymph tubes of the wall of the intestines, onward into the main lymph duct. (See Figs. 15 and 25.) The chyle cannot return to the lacteal when the muscles relax, on account of the valves, similar to those of the veins, in the lacteal at the base of the villus. Then, when the muscles relax, the lacteal is empty, and ready to absorb more of the emulsified fat that we call chyle.

**Routes of Different Foods after Absorption.** — In the villi the largest part of the work of absorption is done. The fats are absorbed by the lymph capillaries, or lacteals, and the rest of the foods by the blood capillaries. It should be carefully noted that nearly all of the foods but the fats go at once to the liver, through the portal vein; but the fats are carried by the main lymph duct (the thoracic duct) to be emptied into the subclavian vein under the left collar bone; hence they do not pass through the liver. (See Figs. 15, 24, and 25.)

NOTE. — If a solution of salt and one of sugar are brought into contact, they will gradually mix by *diffusion*. If these two solutions are separated by parchment, they will still diffuse through the membrane and mingle. This is *osmosis*. Since substances differ in the readiness with which they pass through a membrane, they may be thus separated. Such separation is *dialysis*, and the membrane is called a dialyzing membrane. In the digestive tube the mucous membrane represents the dialyzing membrane with blood or lymph

[1] Howell.

on one side, and the contents of the digestive tube on the other. Soluble materials, such as peptones, sugars, etc., pass through the mucous membrane into the blood.

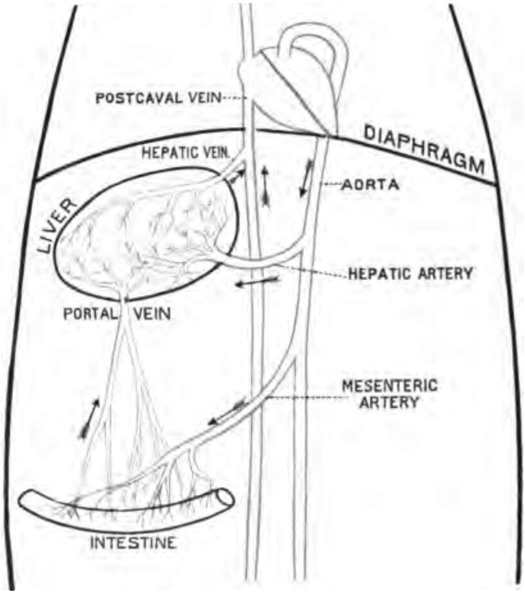



Fig. 24. — Diagram of portal circulation

**Important Facts about the Digestive Tube.** — The whole digestive tube may be briefly and roughly described as a muscular tube of varying diameter, lined by mucous membrane. The muscular coat propels the contents and mixes them with liquids by repeated wavelike contractions called *peristalsis*. The mucous coat is beset with glands, making liquids, some of which merely soak the food, others act on it chemically, while mucus serves to moisten the surface. It seems that these myriads of simple glands are not enough, so several large compound glands lie alongside the food

tube and empty their secretions into it by ducts; these supplementary glands are the salivary glands, the pancreas, and the liver.

The length of the small intestine is about twenty-five feet, and of the large intestine five or six feet. The large

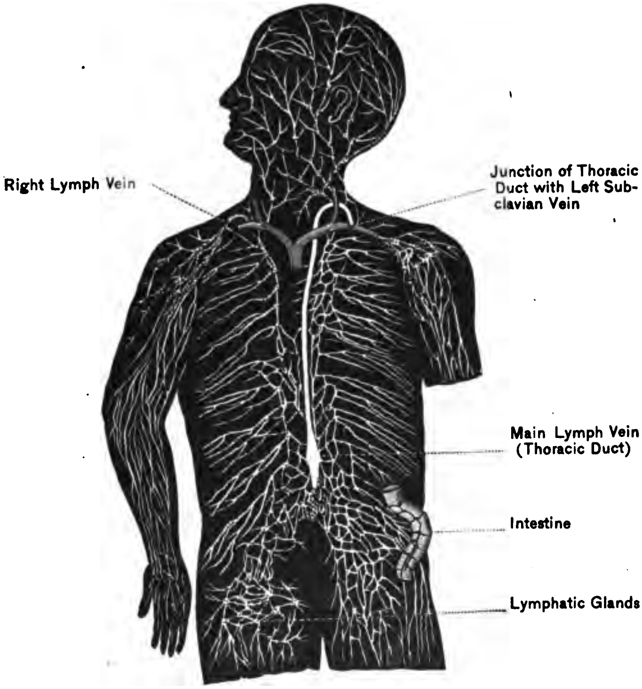



Fig. 25. — Lymph veins — Lymphatics. (Ventral view.)

intestine is not a direct continuation of the small; that is, the small intestine opens at a right angle into the large near the beginning of the latter, so that there is a short blind end called the *cecum*. In some animals this is large and has considerable length, but in man it is very short.

It seems to have been longer in man's ancestors, for there is a closed prolongation of the cecum, the vermiform appendix. This appendix is frequently the seat of serious or fatal inflammation, called appendicitis.

The small intestine joins the large near the lower right side of the abdomen. The main part of the large intestine is called the colon. The last part is the rectum. (See Fig. 26.)

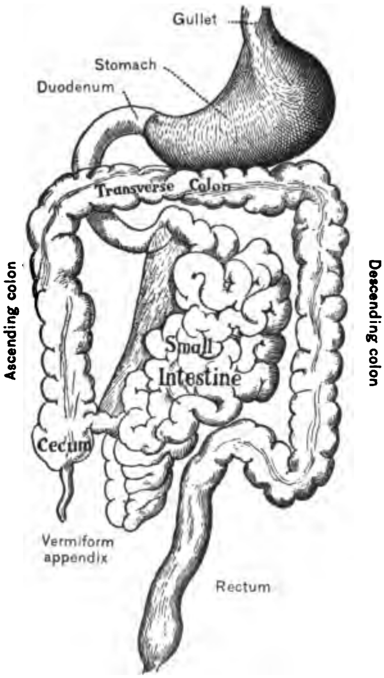


Fig. 26. — Stomach and intestines

**The Work of the Large Intestine.** — Most of the absorption is accomplished in the small intestine; but as the food passes on into the large intestine the work of absorption is carried somewhat further. If the waste be not soon expelled, there may be absorption of some of the results of putrefactive changes, and a sort of general poisoning of the whole body. Hence the great importance of regularly and thoroughly emptying the lower bowel. The matter thus expelled is largely made up of indigestible material, with some real waste substances — the *feces*.

**Constipation.** — This is a very common disorder, and the evils attending it are many. It is well known that certain

foods tend to bring on such a condition, and that other foods have the opposite tendency. Thus, cracked wheat and oatmeal are generally considered as somewhat laxative in their effects. Fruits generally are laxative. The coarse particles of graham flour are irritating to the mucous lining of the stomach and intestines, and for many persons stimulate the action of the bowels. But in many persons the mucous coat is so sensitive that it cannot bear such irritation. For these the "entire-wheat" flour may serve the same purpose. Each person should find out by experience what is best for him; no rules can be laid down that will apply to all cases. But it may be well to know what is the usual effect of some of the common articles of food, as perhaps some persons may habitually partake of certain articles and do not suspect that they are the cause of the trouble.

TABLE OF FOODS[1]

| *Laxative* | *Constipating* |
|---|---|
| Rolled and cracked wheat bread, gems, biscuit, griddlecakes. | Hot bread. |
| Crackers and mush from flour of the entire-wheat and graham flour. | White bread. |
| Granula. | White crackers. |
| Bran gruel and jelly. | Black pepper and spices. |
| Fruit puddings. | Pastry made of white flour and lard. |
| Fruit pies. | Bread, rolls, dumplings, etc., made with baking powder. |
| All fresh acid fruits, including tropical fruits, like bananas, oranges, lemons, etc. | Cake. |
| Dried fruits. | All custard puddings. |
| French prunes and prunellas, eaten raw. | Salted meats. |
| | Salted fish. |
| | Dried meats. |
| | Dried fish. |
| | Smoked meats. |

[1] This table need not be memorized.

| *Laxative* | *Constipating* |
|---|---|
| Stewed dried fruits, of which peaches, plums, and prunes are the best. | Poultry. |
| New Orleans molasses. | Cheese. |
| Rhubarb. | Chocolate. |
| Onions. | Cocoa. |
| Celery. | Boiled milk. |
| Tomatoes. | Tea. |
| Cabbage, raw. | Coffee made of wheat, corn, barley, toast, etc. |
| Corn. | Beans, dried. |
| Squash. | Farina. |
| Cauliflower. | Sago. |
| Green peas. | Starch. |
| Spinach. | Tapioca. |
| Beets, etc. | Rice. |
| Liver. | Raspberries. |
| Oysters. | Blackberries. |
| Wild game. | |

**Other Ailments of the Alimentary Canal.** — Ordinary colds may predispose the mucous membrane of the food tube toward various ailments or diseases. Catarrh is usually a chronic congested condition of the mucous membrane. It may be acute in the stomach, called gastritis, and is serious enough to need the advice of a physician.

Chronic indigestion or dyspepsia is not infrequently due to this cause. Improper eating of food and iced things is also a predisposing cause. For adults there is no definite remedy, but hot drinks before meals and after give relief. For young people the wise course is prevention by partaking moderately of pure food and drink and avoiding colds. Much discomfort and pain will be avoided by heeding this rule.

More serious diseases are typhoid fever and appendicitis.

(See Fig. 26.) Approaching appendicitis may cause pain mainly on the right side of the abdomen, but pain in the abdominal region is not uncommon, and is often due merely to gases arising from faulty digestion or from improper food. A cup of hot water or other hot drink will relieve ordinary pain in the abdomen. However, when pain persists and is accompanied by a rise of temperature, there is danger, and a good physician should be consulted.

*Typhoid fever* is a disease caused by the presence in the food tube of a certain germ,[1] which causes only this disease. It is sometimes called a filth disease because it is taken through water, milk, or other food infected with particles of dejecta from a typhoid patient. Careless nurses may help spread the disease by allowing visitors to touch patients or their bedding, or by allowing flies to settle on the dejecta before the latter are disinfected. It would be better if no visitors were admitted to the sick room.

*Cholera* is not common enough, except in seaport towns, to need more than passing mention. It is taken through infected water and food, and may be fatal in a few days. If one is in good health, the normal acid gastric juice kills the germs, and he will not take the disease though the germs are swallowed.

"Summer complaint," a form of diarrhea more often due to taking cold than to unripe fruit,—which is popularly blamed,—is not serious.

**Parasites.**—The intestine may harbor various parasitic worms, such as tapeworms (see page 74), threadworms, and hookworms. Tapeworms are taken through eating raw meat, so the remedy is prevention; never eat raw or partly cooked meat. Children may get worms from pet

[1] See Chapter XVI.

cats and dogs. Hookworms are taken through food and by an itchlike infection of the minute young. They are

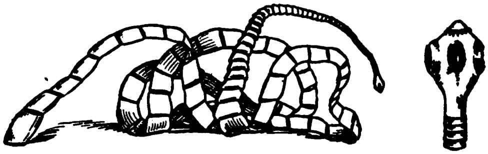


Fig. 27. — Tape-worm
Note enlarged head at right. It is the smaller end in the whole worm.

found in damp earth and may enter the body through skin bruises.

**Alcoholic Dyspepsia.** — Careful experiments show that alcohol in such quantity as is taken in habitual drinking retards digestion; the fact is that alcoholic dyspepsia is one of the most common effects of habitual drinking. The stomach is first acted upon by alcohol; it usually becomes inflamed, and this condition may become chronic. The liver, under the influence of alcohol, develops an abnormal growth of connective tissue and takes on the characteristic appearance by which it is designated as the "hob-nailed liver."

Read the story of Alexis St. Martin, the Canadian trapper, whose stomach had an opening to the outside, through which the work of digestion was studied by Dr. Beaumont. See Appendix, *Pathfinders of Physiology*.

### QUESTIONS FOR REVIEW

1. What are some desirable surroundings for a meal?
2. What mental conditions disturb the digestion of food?
3. In what ways may a "weak digestion" be improved?
4. Why is it better to eat three times a day?
5. What is the popular idea about absorption from the stomach?
6. What is the truth?

7. What is meant by "absorption a vital process"?
8. Describe the construction and action of a villus.
9. How are fats carried into the blood?
10. Where are digested proteins and sugar carried?
11. What is the length of each intestine in man?
12. What diseases affect the alimentary canal?
13. Which are germ diseases? What parasites may be found in the food tube?
14. Why should not children handle cats and dogs?
15. How does habitual drinking of alcoholic liquors affect the digestive tube?

## EXERCISES

*To illustrate Mechanical Absorption of Food through Intestinal Membrane.* — 1. If there is time for only a simple illustration of mechanical absorption, called osmosis, the following may be tried: The shell on the large end of an uncooked egg is carefully broken over an area about the size of a dime. There is an air space in this end of the egg over which the shell may be removed without breaking the membrane. The egg is then laid in a dish of water or of liquid food. The interior of the egg represents the wall of the intestine into which liquid food is absorbed. The next day look for evidence of absorption through the membrane. What indicates the force with which absorption took place? A glass tube may be fastened with plaster of Paris in a hole made in the side of the egg to make an osmometer of the egg. See 3, (*a*) below.

2. Two sections of intestinal membrane are prepared as in exercises for solution, page 56. No. 1 is filled with starch paste alone; No. 2 is filled with a mixture of starch paste and pancreatic juice, or saliva. Each membrane is suspended in a tumbler of water. Next day, the water outside of each membrane is tested for grape sugar. In what condition must food be to pass through the intestinal wall? How shown? This illustrates the mechanical process of absorption. It applies more particularly to digested carbohydrates, while the absorption of emulsified fat and peptone is believed to be accomplished by the living cells in the intestinal walls.

3. If a piece of glass tubing about 8 inches long is tied into the mouth of each membranous bag, and the bag is filled with more of

the same liquid up to a mark on the tube, we can tell whether liquid passes into or out of the membrane, (*a*) as shown by the level of liquid in the tube; (*b*) as shown by the sugar test of the water outside the membrane. Which way does flow take place when a digested food and a liquid are separated by a membrane; which way when an undissolved food is separated from water?

4. To demonstrate villi: The intestinal membranes that were procured for digestion exercises (See note under Solution in Water, page 56) are cut into rings about a quarter of an inch long and these then studied in sauce dishes of water. A magnifier will aid in seeing the structure of the mucous membrane.

# CHAPTER V

## THE CIRCULATORY SYSTEM

**Notions about Blood.** — There is much superstition and ignorance about the blood in our bodies. On the one hand, it has been associated with incantations and imprecations; " blood for blood," is the cry of the avenger. On the other hand, it is popularly supposed to contain the life of the body, and the phrase, " cut to the quick," means drawing blood. Fainting at the sight of blood is a weakness that some people cannot overcome.

**Importance of a Knowledge of Blood.** — The subject of blood is an important and interesting one. A thorough knowledge of blood and its distribution in the body explains not only fainting and growing pale, but also blushing, nausea, vertigo, headache, " taking cold," inflammation, how the tissues are nourished, and other important things.

### How the Living Tissues are Nourished

**Colorless Blood Important.** — At one time the red blood was believed to saturate the tissues everywhere, as water does a sponge, because the finest pin prick draws blood. This is true only of the colorless blood, or *lymph*, as it is called, which fills all spaces between living cells. In this way the cells are able to use the liquid food (see Digestion, page 67) which is brought in the lymph from the digestive organs. Each cell may be compared to an individual ameba, which lives in water, and throws all its waste

products into the same water. As water is the medium in which the ameba lives, so we may say lymph is the medium in which the cells of the body live.

Now the ameba can move about in the water when it has exhausted the food in one place and made the water impure. Not so with the body cells, as they are fixed in position. If a group of amebas were entangled somewhere, we might keep them alive by moving along the water which contained their nutriment. This is just what happens in the body. The lymph is kept moving along among the cells by pressure from the heart. (See page 99.) The lymph spaces are smaller than the cells, so that they cannot carry enough lymph to supply many cells. After passing a number of cells, the lymph finds its way into delicate lymph tubes. (See Fig. 28.)

**How Lymph Moves, Massage.**—We can now understand how much our health depends upon the flow of this lymph, since it brings nutrient material for the life of the cell and carries away the waste of the cells. Its natural movements may be increased by muscular exercise and by a system of pressing, rubbing, and kneading the muscles, known as *massage*. It helps the flow of the blood and lymph, thus aiding in washing out the waste products from the muscles and other parts of the body that are to be reached by pressure. We have seen that one of the benefits of exercise is to promote the circulation of the blood and of the lymph, and so to help get rid of the waste matters that are produced by the activity of the various organs. Many invalids cannot take active exercise. So this passive exercise may very fairly take its place and assist in the nutrition of the tissue by accelerating the flow of blood and lymph, bringing new nourishment and carrying away wastes. For students who

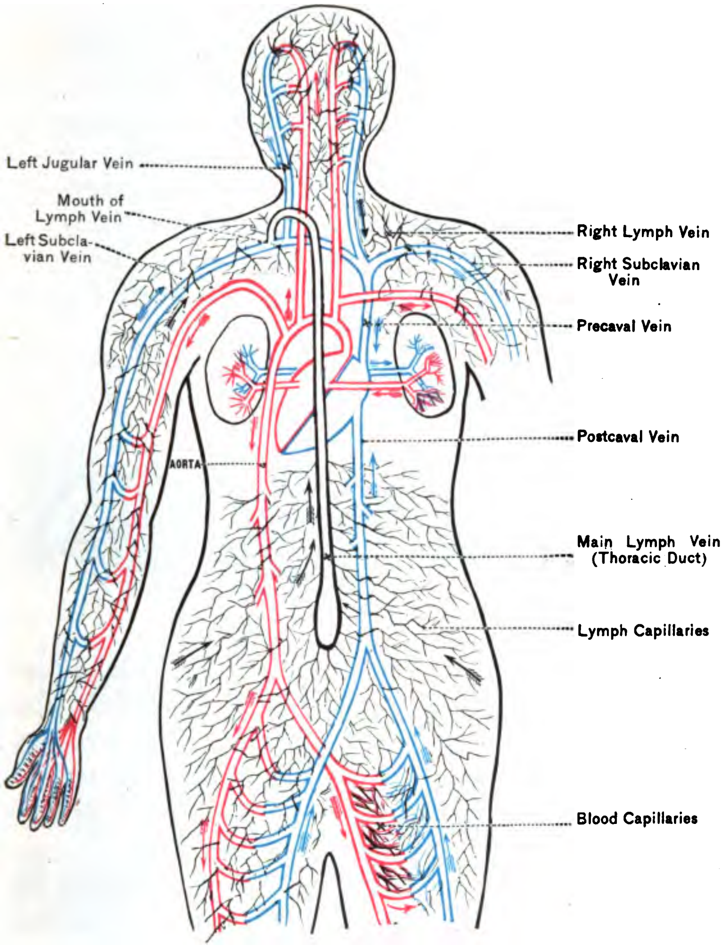



Fig. 28. — Diagram of the circulation of blood and lymph (Dorsal view).

do not take sufficient exercise it is a good thing to rub the body thoroughly and briskly, not only after a bath, but often with the hands or with a dry towel. What would

the lymph bring from the small intestine after a meal? The answer will be found in the chapter on Absorption.

**The Home Journey of Lymph.** — The smallest lymph tubes, mentioned above, are called *capillaries* because, even under the microscope, they seem as fine as hairs. From these the lymph is forced into larger tubes, the *lymphatics*.

**Valves help the Movement.** — In these tubes the lymph is kept from returning by valves which act a little as the turned-in flap of a coat pocket does when you try to withdraw your bent fingers from the pocket.[1]

**Lymph Filters.** — On the course of the lymphatics there are also nodules or filtration masses called *lymph glands*.


Fig. 29. — Lymph tubes of the surface of the arm

Here the lymph is more or less purified. Two of the largest lymph glands are in the armpits and in the groins. (See Fig. 29.) Almost every one who has had a very sore hand or foot remembers the soreness in *axilla* or groin, and this is said to be due to the overworked lymph glands in these regions. They remove poisons from the lymph.

**Lymph Trunks and Receptacle.** — After the lymph has done its work of distributing nourishment to the cells of the tissues, and receiving much of their waste and impure

[1] It would be well for some student to make a tube of canvas or stout cloth, three inches in diameter and about one foot long, with one or two pocket valves sewn inside near the middle. Then let him pour sand, bran, or water through the tube both ways, to show the class how such a valve works.

material, it is carried by the delicate lymph tubes or lymphatics into a large tube (one fourth inch in diameter) centrally located in the body, beginning near the middle of the abdominal cavity. It passes straight up to the region of the neck and empties its lymph into a vein (the left subclavian), which in turn empties into the heart. This great lymph tube, also called the *thoracic duct*,[1] is large enough so that the lymph in it is under no pressure; but it is under pressure in the cells, and therefore lymph naturally flows from the tissues toward the larger duct.

The thoracic duct receives the lymph from four fifths of the body, from all except the right arm and the right side of the head. From these regions a separate lymph duct empties the lymph into the right subclavian vein. (See Fig. 30.)

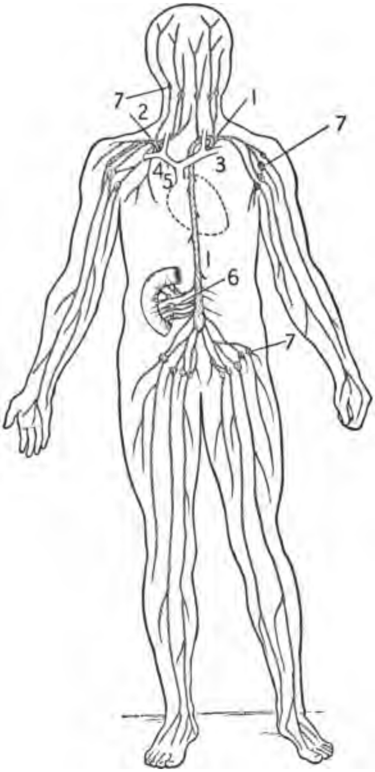



Fig. 30.—Diagram of drainage system for the lymph

**1. Thoracic duct. 2. Right lymphatic duct. 3. Left subclavian vein. 4. Right subclavian vein. 5. Superior vena cava. 6. Lacteals. 7. Lymphatic glands. The small tubes connecting with the lymph spaces in all parts of the body are the lymphatics.**

[1] So called because it passes up through the thorax, *i.e.* the chest. Besides the lymph the enlarged part also carries the chyle and is called the receptacle of the chyle. Where does the chyle come from?

**Red Blood: How Carried.** — But whence came the lymph or colorless blood? How did it get into the cell spaces? To understand this, let us go back to the statement that though red blood is drawn by the finest pin prick, it does not saturate the tissues as water does a sponge; that the lymph does this. The reason that the red blood is brought to the surface so easily by the finest cut is because it is also distributed through all parts of the body in microscopic, thin-walled tubes finer than the lymph capillaries. These tubes are called *blood capillaries*, because, commonly, the name *blood* means red blood. The capillaries have extremely thin walls, so thin that the liquid part of the blood can soak through them into the tissue spaces.

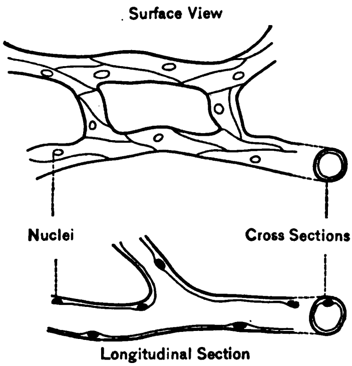


Fig. 31. — Capillaries, composed of a single layer of cells

**Source of Lymph.** — Here we learn the chief source of lymph. It is the liquid, colorless part of the blood, filtered through the walls of the blood capillaries under pressure from the heart. Thus it bathes the living cells. Now if we wonder why capillaries are needed to confine the red blood, rather than the slower moving lymph, in definite channels, the answer probably would be: that the red blood, with the remaining colorless blood liquid, or *plasma*, must be sent through the body more rapidly to furnish oxygen enough to all the tissues so that they shall not suffocate; for it is the red blood only that can carry the oxygen from the lungs to the tissues.

**Red Blood in Other Animals.** — In many lower animals the red coloring matter of the blood is in fluid form. This is the case in the earthworm. But in our blood the red coloring matter, the *hæmoglobin*, is held by myriads of floating disks of protoplasm. These are a little smaller than the blood capillaries through which they flow or are carried by the moving plasma. The little red blood bodies, *corpuscles* (from Latin, *corpusculus*), are composed of living protoplasm and are generally considered as floating cells, but they have no nuclei.[1] (See Figs. 32 and 34.)

**The Use of Hæmoglobin.** — The hæmoglobin is a peculiar-colored protein capable of combining with and holding oxygen until it gets to the capillaries that pass through tissues where there is no oxygen.[2] Here the oxygen leaves the red corpuscles, diffusing to the cells. And now the hæmoglobin, robbed of its oxygen, becomes a dull bluish red. The change in color of the red corpuscles also affects the general color of the blood in the veins, as we shall see. It is estimated that there are 25,000,000,000,000 red corpuscles in the blood of an adult (Howell).

**Iron in the Blood.** — An unfailing part of the composition of red corpuscles is the iron that is present. While the oxygen does not combine with the iron, the presence of the iron is absolutely necessary in order that the oxygen may be held by the hæmoglobin to form *oxyhæmoglobin*.

**The Colorless Corpuscles.** — Interesting and valuable though the red blood corpuscles are as oxygen carriers, there are other corpuscles in the plasma as valuable, and

[1] In only one genus of mammals, the dromedary, do the red blood corpuscles have nuclei. (See Chapter I, Introductory.) The blood is generally considered a tissue.

[2] In single corpuscles, as seen under the microscope, the color appears so pale as to look yellow. In some animals hæmoglobin has other colors.

more interesting in their way. They are in general designated as white or colorless corpuscles and are of two kinds. The commoner ones are called *leucocytes*, and are the only ones that need engage our attention.

**The Story of the Leucocytes.** — They are slightly larger than red corpuscles, and are true ameba-like cells having

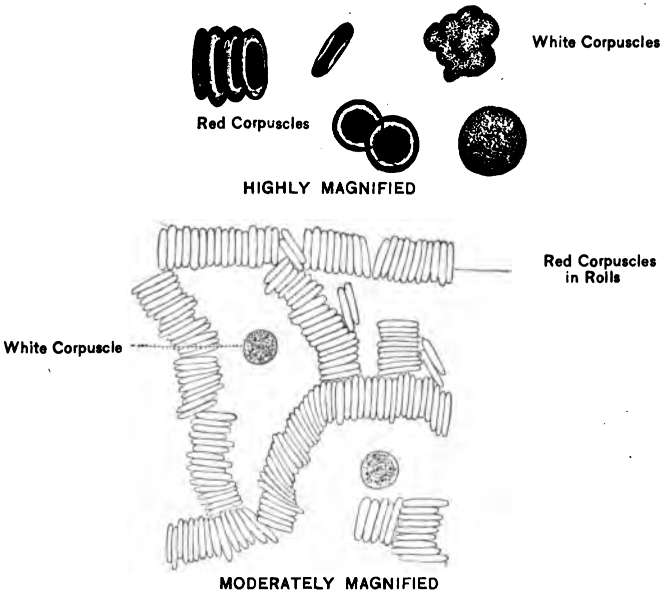



Fig. 32. — Red and white corpuscles of the blood

nuclei. (See Fig. 32.) On account of their ameboid character they can crawl or force their way through the soft, thin walls of the blood capillaries and wander about in the lymph-filled tissue spaces, "seeking whom they may devour"; for their nature is truly voracious and warlike. (See Figs. 33 and 34.) They destroy hostile germs in the blood and tissues. During an attack by a larger number of germs the

plasma of the blood actually forms substances, *opsonins*, which coat the germs and act as a sort of relish to the

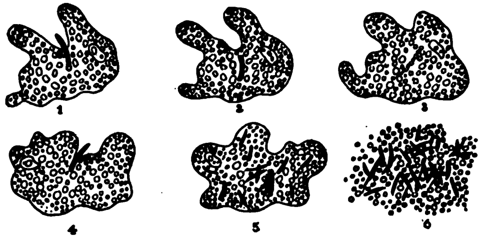



Fig. 33. — Showing leucocyte destroying a germ — upper row. In the lower row (4, 5, 6), germs were victorious and the leucocyte is killed

flagging appetite of the leucocytes. Foreign organic particles, such as pieces of cells, are also engulfed and made

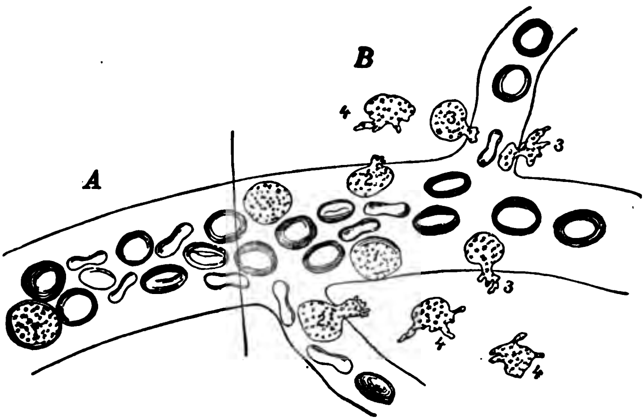



Fig. 34. — Escape of white corpuscles from a small blood vessel (Hall)

At *A* the conditions are normal, but at *B* some excitation in the surrounding tissue leads to a migration of corpuscles. 1, 2, and 3 show different stages of the passage

harmless. Because of these two characters the leucocytes have also been called *phagocytes*, the name meaning "to devour cells."

**The Discovery of Phagocytosis.** — A Russian biologist, Metchnikoff, in the Pasteur Institute, France, discovered the phagocytes at work while he studied, through the microscope, the effects of a pin prick in the web of a frog's foot. The phagocytes soon collected around the wound and enveloped the germs that were introduced by the pin, and also the bruised cells.

NOTE. — This experiment illustrates what happens when we cut or prick the skin with an infected instrument and thus inoculate it with germs. The injured cells and foreign germs stimulate the leucocytes to come to the injured spot. If they can dispose of the germs, the wound heals and we think nothing further about it. But if the system is not in good condition and the phagocytes are not able to kill the invading bacteria, more blood will come with more leucocytes to destroy the poisons (*toxins*) secreted by the germs. This heaping of blood around the wound area is *inflammation*, marked by pain, redness, and swollen feeling. When the invading bacteria are victorious, the leucocytes disintegrate and form the pus, or "matter" in a wound.

**Clotting of the Blood.** — The leucocytes are similarly summoned when a blood tube is wounded. They give out a substance (ferment) which causes the protein (*fibrinogen*) in the blood to clot by forming fibrin or fibers, which are the important part of every clot. Thus the leucocytes act as sort of Red Cross workers in the body.

**The Leucocytes form Protein.** — In fact, they are such unselfish servants that when there is not enough protein nourishment in the blood, they give up their very existence by melting into the liquid of the blood as a drop of jelly might melt in warm water. Being almost pure protoplasm, this enriches the blood plasma. Besides these, they serve minor uses — such as assisting in the absorption of digested products — and yet investigators tell us that their original

function is not surely known. All these activities so far described may be secondary duties.

**Summary of Uses of Leucocytes.** — To summarize the duties of the leucocytes, we may say they act: (1) As scavengers and health officers, removing waste substances and harmful germs. (2) They give out (secrete) a ferment that makes blood clot. (3) They can increase the protein content of the blood.

**Blood Plates.** — There are also blood plates which seem to be halfway between disks and ameboid cells. They are believed to favor coagulation.

**Functions of the Plasma.**— Before going further it may be well to complete our knowledge of the blood fluid or plasma in which the corpuscles and plates float. It contains the digested, therefore fluid, nutrients, proteins, fats, and sugars. Besides being the bearer of nutrients to be carried to the tissues, and of waste matter to be taken away from them, it has a property quite as remarkable for combating disease germs and their poisons as the leucocytes have.

When any foreign substance comes into the blood, as germs, — dead or alive, — or their poisons, there are formed in the serum [1] antidotes that are called *antibodies* or, lately, *antigens*.

**Vaccination, Inoculation, Antitoxin.** — When the body is in vigorous health, we do not succumb to ordinary disease. As the body is not always in its best condition we may need for protection the help of an injection of anti-substance formed in the body of another animal. A familiar example of this is vaccination against smallpox. The virus inocu-

[1] The serum is the liquid of the blood left after clotting — pale, yellow, and watery.

lated in vaccination passes into the blood and causes *antigens* against smallpox. The antitoxin injected for diphtheria is formed in the blood of a horse by injecting diphtheria poison into its veins. This causes antibodies (antitoxin) to be formed in the blood of the horse. Immunity for three years from typhoid fever is now secured by injecting *killed* typhoid germs under the skin of the arm or leg.[1]

**The Veins.** — After having learned how the lymph — the part of the plasma that filters through the capillaries

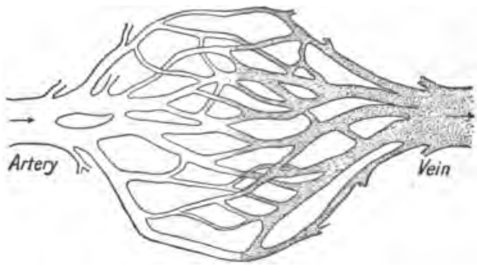



Fig. 35. — Artery, capillaries, and vein
The shading indicates the change in the color of the blood

— is collected in lymphatics to be returned to veins, we must next follow the rest of the plasma and the red corpuscles from the capillaries, which unite to form the veins. Just as water rivulets form larger creeks or brooks, and these form rivers, so the capillaries unite to form the smallest veins. (See Fig. 35.) These in turn unite to form the larger veins, such as the subclavian, into which, as we have already learned, the lymph tubes empty. On the back of the hands and on the arms we can see how the smaller veins join to make the larger ones. (See also Fig. 36.)

[1] The germs are killed in a pure culture made for the purpose.

**Bleeding from the Veins.** — Blood pressure from the heart is not very great in the veins, since it is counteracted

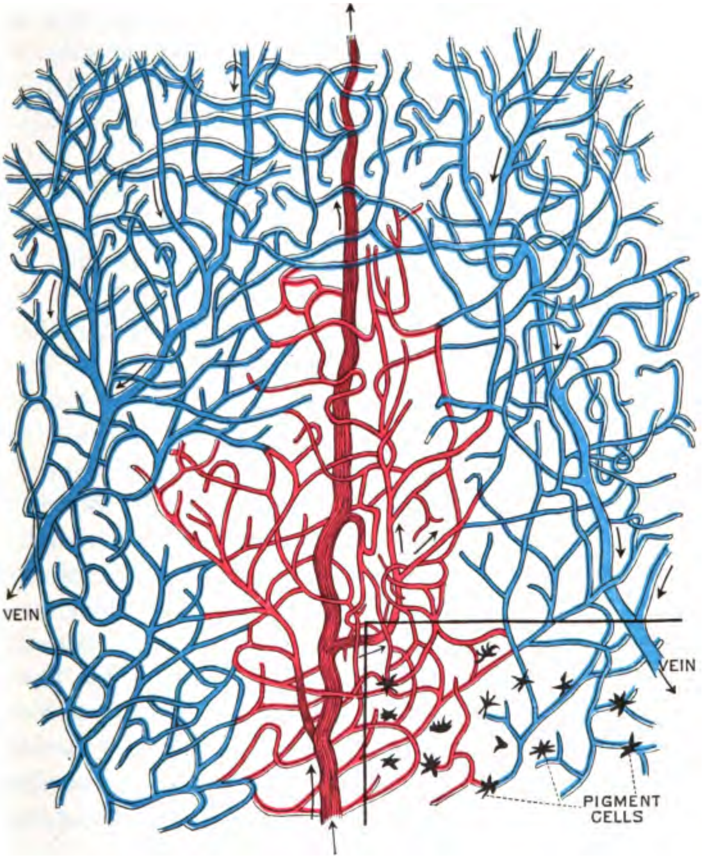



Fig. 36.—Part of frog's web (low magnifying power)

by the small bore and large number of the capillaries. Bleeding from cut veins is therefore neither very rapid nor

very dangerous. Would you be able to tell which side of a cut to press on a wounded vein in order to stop bleeding? If you cannot tell, look it up in the chapter on Accidents.

**The Use of Valves in Veins.** — We may wonder why the blood does not come back from the heart end of the wounded vein. If we will recall the pocket valves in the lymphatics, we can give the probable answer. Especially in the smaller veins there are numerous valves. (See Fig. 37.) We can readily see that these valves are necessary to help raise the blood against gravity in a limb, for instance, the hanging arm or the leg, just as valves are needed in a pump to raise water against gravity. If there were no valves in the pump, the water would settle back, after each stroke, as far as it had been lifted.[1] So the blood, lifted more or less vertically through any vein, is kept from falling back by valves. It is important to note that they all have the mouths of the pockets toward the heart, so that the blood flows freely toward the heart, but is prevented from flowing the other way on account of the filling of the valves by the reflow of the blood stream. When the blood is flowing through the veins toward the heart, the valves lie against the walls of the veins.

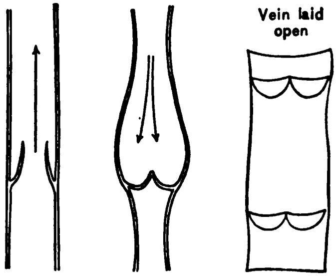


Fig. 37. — Valves in veins

The valves are most numerous in the medium-sized veins, and especially in the veins of the extremities. They are more abundant in the leg than in the arm. Valves

[1] This may be illustrated by the pump figured in the Appendix.

are absent from the caval and some other veins, and from the very small veins.

**Evidences of Valves in our Veins.** — With the forefinger stroke one of the veins on the hand or wrist toward the tips of the fingers. The veins swell out. The blood meets resistance in the valves of the vein. Their location may be determined by their bulging out during the experiment.

Stroke a vein toward the body, and the blood is pushed along without resistance.

Let the left hand hang by the side. Note the large vein along the thumb side of the wrist. Place the tip of the second finger on this vein just above the base of the thumb. Now, while pressing firmly with the tip of the second finger, let the forefinger, with moderate pressure, stroke the vein up the wrist. It may be seen that the blood is pushed on freely, but comes back only part way. It stops where it reaches the valves, filling the vein full to this point, but leaving it collapsed beyond, as shown by the groove. Remove the second finger, and the vein immediately fills from the side nearer the tip of the fingers.

These experiments show that the blood in the veins moves freely toward the body, but cannot flow outward to the extremities.

**Effect of Pressure on the Veins.** — Since the valves in the veins open toward the heart, any intermittent pressure on the veins helps to push the blood on toward the heart. The valves are most numerous in the superficial veins and those of the muscles. The pressure of the muscles during their action (thickening while shortening) produces pressure on the veins; and as the muscles act for a short time only, and then relax, this alternate compression and release aids very considerably in moving the blood on toward the heart. It is worthy of remark that this effect is more pronounced at the time the muscles need the most active circulation; namely, when they are in action and are using the most blood. The heart has power enough to pump the blood clear around from each ventricle to the auricle

of the other side of the heart; but this outside aid comes in good play to relieve the heart at a time when it has an unusual amount of work to do, as when one is using a large number of muscles vigorously.

"Every active muscle is a throbbing heart, squeezing its blood tubes empty while in motion, and relaxing so as to allow them to fill up anew."

**Varicose Veins.** — In the large veins of the legs of older people and of those who stand much, the valves may become weakened or may break away. The accumulating blood then makes the veins bulge out under the skin, forming large bluish ridges — the so-called "varicose veins." This malady is painful but not usually dangerous. Temporary relief is obtained by resting the legs in a horizontal position, and more permanent relief by winding a bandage rather tightly around the leg, beginning at the ankle. There are elastic stockings sold at drug stores for the relief of this malady.

**The Vein Trunks: How Formed.** — As stated before, the blood flows from all capillaries through the veins[1] to the heart. If we carefully study the diagram on page 93, we see that the larger veins from the lower part of the body form the postcaval vein, and those from the anterior or upper part of the body form the precaval vein. Both of these veins bring the blood from all parts of the body to a thin-walled cavity or chamber in the heart, which is called the *right auricle.*

**Blood passes through Right Side of Heart.** — While the right auricle is filling, blood passes through it into the next cavity or chamber, the *right ventricle.* This chamber extends downward to a little above the apex of the heart.

[1] This is the correct designation of veins: vessels that bring blood to the heart. The popular designation "vessels that carry impure blood" has one exception.

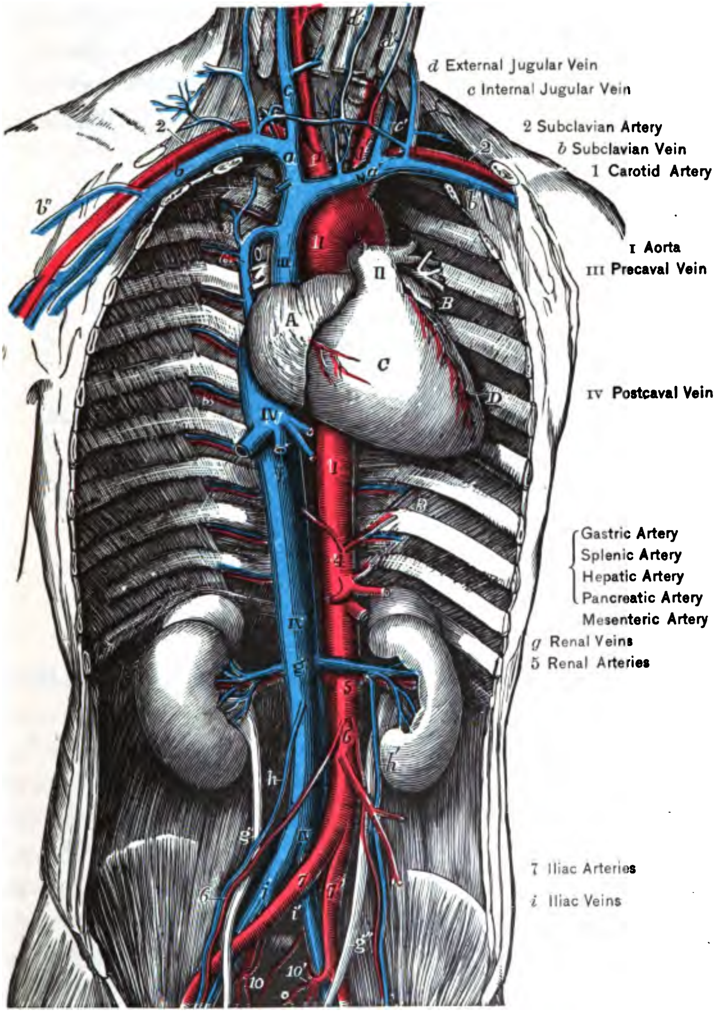



Fig. 37 a. — The larger arteries and veins

(Compare Figs. 38 and 39.) The somewhat narrow passage between the two chambers is provided with three skin-like flaps, the tricuspid valve. They are fastened in the floor of the auricle and hang into the ventricle chamber as trapdoors might hang by hinges into a room below. While the

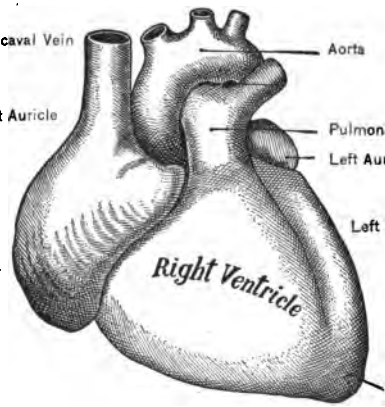



Fig. 38.—The right side of the heart
The heart, from the front

ventricle chamber fills with blood, the trapdoor valves float upward as if closing.

**Contraction Wave of the Heart.** — Now a wonderful thing happens. The auricle at first slowly puckers up or contracts, then finishes rapidly and thus forces the ventricle full of blood, and the tricuspid valve closes. (See Fig. 39.) By contraction is meant the closing or squeezing of the heart to force along the blood. The contraction wave passes on to the ventricle and it also contracts, and since the tricuspid valve is closed and is firmly held by tendinous cords, the blood finds and forces open another kind of valve, the *semi-lunar*, opening into an artery, a blood tube that

carries the blood from the heart to the lungs. From the Latin *pulmo*, meaning "lung," this artery is called *pulmonary artery*.

**Arteries from the Heart.** — The pulmonary artery is an exception to the popular notion that arteries carry pure blood, but it will help us to remember that the tubes that carry blood from the heart to any other organ are called *arteries*, no matter what kind of blood they carry.

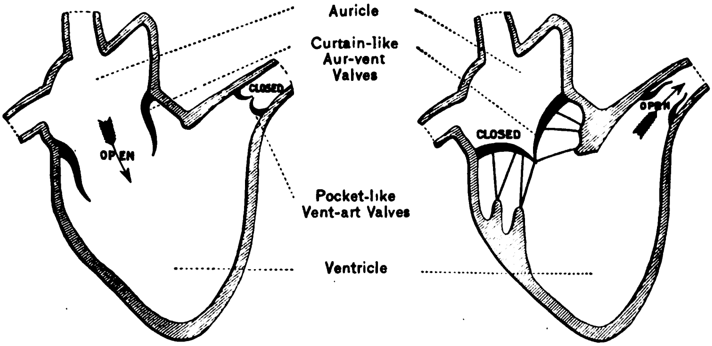



Fig. 39. — Diagram of the heart, showing the action of the valves

**Need of Valves.** — The tricuspid valve is necessary to prevent the blood from flowing back into the auricle chamber. Otherwise the blood would not force open the semi-lunar valves and be pushed on into the pulmonary artery. The pulmonary artery is more elastic[1] than veins are, and when stretched by the forcing action of the heart, it presses on the blood, helping to drive it into the capillaries of the lungs — the pulmonary capillaries. Here again we see the necessity of the semi-lunar valves at the mouth of the pul-

[1] It is important to understand the correct meaning of elasticity. It does not mean, as it is popularly used, "easily stretched," but the completeness with which a body returns to its normal shape after being stretched.

monary artery to prevent the elastic reaction of the artery from forcing the blood back into the ventricle while the heart is resting.

**The Left Side of the Heart.** — After the blood is purified[1] through the lung capillaries, how does it get to the organs of the body where it is needed? So far the description has covered only the right side of the heart. In some animals

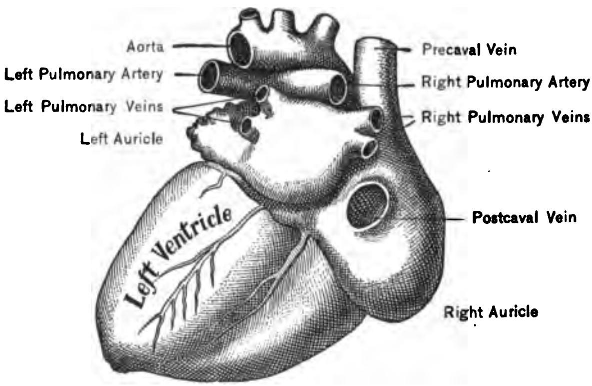



Fig. 40. — The left side of the heart
The heart, from behind

(fishes) the purified blood goes directly to the tissues, and a single heart does the work of forcing the blood through two sets of capillaries. But in birds, mammals, and man the purified blood from the lungs returns to the left half of the heart. This is more muscular, therefore stronger and better able to pump the blood to all organs of the body. We should be able to tell what to call the vessels, or blood tubes, that bring the blood from the lungs to the heart: whether

[1] The heart does not purify the blood, as is popularly believed, any more than a pump purifies the water that is passed through it. The heart acts merely as a pump. Purified here means oxygenated.

they should be called pulmonary veins or arteries. The pure blood received into the left auricle is brighter red, the shade showing in both the pulmonary vessels and in the left auricle. Just as the blood was forced from the right auricle to the right ventricle, so it is sent from the left auricle to the left ventricle, except that the valve between the auricle and ventricle has two flaps instead of three. From its appearance it has been called the *mitral* valve. It will thus be seen that the heart is a double tube, the blood passing through the right tube on its way to the lungs and through the left tube on its way to the organs of the body.[1]

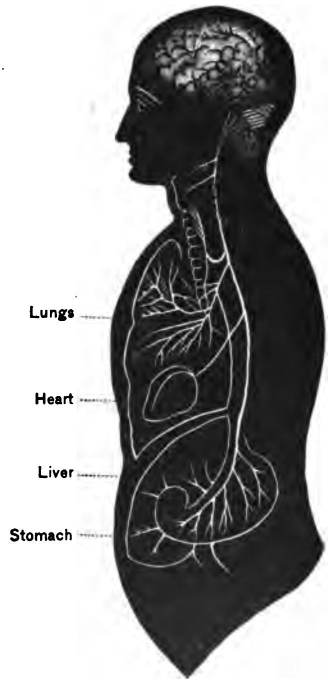


Fig. 41.—Diagram of vagus nerve

**The Heart as the Seat of the Emotions.**— Since time immemorial the heart has been considered the seat of the emotions, such as fear, anger, hatred, sorrow, joy, and love. "From the abundance of the heart the mouth speaketh." "It nearly broke his heart" is a common expression and indicates the uneasiness, if not the pain, in that region due to the emotion suffered. For this belief there is the simple explanation that these "emotions" are "felt" in the region of the heart because of the effect of the emotions on this organ through the nerves from the brain. Among some nations similar emotions are

[1] In fact, in the development of a chick the heart is at first a pulsating artery (tube) which gradually grows S-shape and then doubles on itself.

attributed to the stomach. The physiological explanation is that the same nervous mechanism sends branches of nerves to the heart, stomach, throat, and the face. "White with rage," indicates the effect anger has on the face, and it is bad for the heart. (See Fig. 41.)

**The Work or Contraction of the Heart.** — The same contraction wave that was described as passing over the right side of the heart passes over the left auricle and ventricle. In fact both auricles contract at the same time, simultaneously, and both ventricles at the same time, ***but following the auricles.***

**Rest and Work of the Heart.** —Now the heart *pauses* while the muscles relax, the chambers open, and are again filled with blood. This is the heart's resting period. It is contrary to the popular belief that "the heart is incessantly working and yet never wears out." It would wear out, indeed could not exist, if it did not rest between its working periods. In fact the heart rests a little longer than it works — a little more than half the time.


Fig. 42. — Showing the heart — a muscular bag
A and P — Aorta and Pulmonary Artery

**Cause and Regulation of Contraction of the Heart.** — If a piece of the muscular ventricle of a freshly killed animal (calf, pig, or ox), in preparation for the market, be put into water with as much salt in it as there is in the blood, 0.8 per cent, the portion of the ventricle begins to beat slowly and rhythmically. In this way it was found out that the salt in the blood is the chemical stimulus that causes the heart to beat or keep up its contractions. We are aware of the fact that the heart beats faster when we are frightened or excited — "My heart is in my mouth," as the phrase

goes. From this we see that emotions affect the rate of heartbeat, and since fear can affect the heart only through the nerves, we learn that the heart is regulated by nerves. There are two such nerves, the *sympathetic*, that make it beat faster, and the *vagus* nerves, that make it beat slower.

**The Sounds of the Heart.** — There are two sounds of the heart: —

1. A short, sharp sound made by the closing of the semilunar valves.

2. Just preceding this sound a longer, duller sound may be heard during the contraction of the ventricles. This is supposed to be due to the vibrations of the walls of the ventricles and of the aur-vent valves.

**The Work of the Left Ventricle and the Aorta.** — The left ventricle must be very strong to force the blood to the extremities of the body; stronger than the right ventricle, which sends blood only to the lungs. As the right ventricle sends the blood into the pulmonary artery, we may expect the left ventricle to pump the blood into a similar artery, and so it does, into the largest artery in the body, the *aorta*. The aorta is a typical artery whose branches carry blood to all organs of the body.[1]

**Action of the Large Arteries.** — The large arteries have in their walls a yellow elastic tissue. When the blood is forced into them, they are stretched. As soon as the ventricle ceases to contract, and sends no more blood into the arteries, they "stretch back." We should not say contract, for it is simply an elastic reaction. As the artery reacts, it presses on the blood, and hence the blood tries to

[1] Some authors say "except the lungs," but this is not correct, for the lungs, as organs, receive blood for their nourishment and work. For the work of the lungs see the chapter on Respiration.

escape in every possible way. It cannot go back, for it fills the pockets of the semi-lunar valves and closes them with a click. A rapid wave is sent forward that gives the pulse, and a slower but still rapid stream flows along the arteries, through the pulmonary artery to the lungs, and through the aorta and its branches to all the other parts of the body.

The elastic reaction of the arteries thus helps to make steady the flow of blood, which is intermittent as it leaves the heart. The medium-sized arteries also have elastic tissue in their walls and regulate the blood flow in the same way.

**The Semi-lunar Valves.** — From the base of the right ventricle arises the pulmonary artery. Within its base, just as it leaves the ventricle, are three pocket-like valves, like "patch pockets." They are in a circle, with their edges touching, and thus surround the opening, with their mouths opening away from the heart. A similar set of valves is within the base of the aorta, which arises from the left ventricle. (See Fig. 39.)

**Variation of the Amount of Blood Needed.** — Each organ requires a supply of blood in proportion to its activity. An actively working organ, like the brain, demands much more blood than bone, practically inactive. Further, working tissues, such as the brain and muscles, need a great deal more blood while they are at work than when they are resting. An organ needing a constant large supply of blood might secure this by having a large artery. But how can the supply be regulated so that an organ may receive, now more, now less, according to its needs?

**Plain Muscle Fibers in the Walls of the Arteries.** — This is regulated by the medium-sized and small arteries leading to the parts. In the walls of these arteries are muscle

fibers of a different kind from those of the skeleton. These fibers are spindle-shaped cells, as shown in Fig. 43, with a

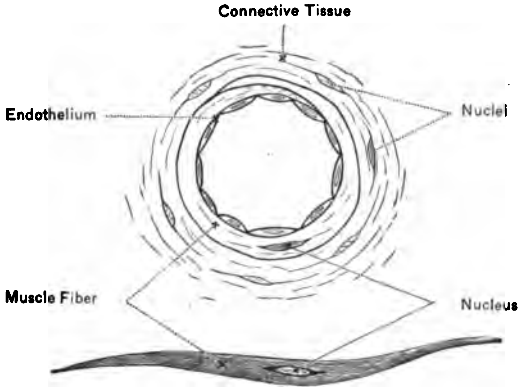



Fig. 43.—Plain muscle fiber; isolated and in wall of artery

nucleus near the center, and do not have the cross markings of the fibers of the skeletal muscles; they are in consequence called non-striated, smooth, or plain muscle fibers. They are arranged circularly in the walls of the arteries. These fibers have, in common with all muscle fibers, the power of shortening. When they shorten, they reduce the size of the artery, and therefore, for the time, less blood can flow through the artery. When the muscle fibers cease to shorten, the artery widens, and allows more blood to pass through it. (See also Fig. 44.)

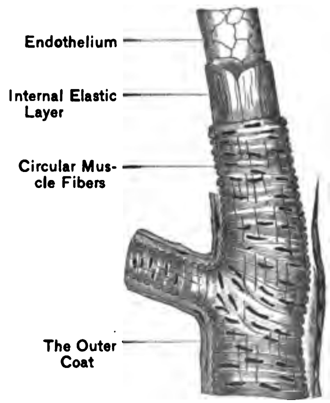



Fig. 44.—Coats of a small artery

**The Effect of the Emotions on Circulation.** — In our everyday experience we have evidence of the control of the heart and blood tubes by the nervous system. We know that certain emotions affect the circulation of the blood and produce blushing and pallor. Certain emotions may also quicken or retard the action of the heart. Excessive grief or joy has produced sudden death by stopping the beat of the heart.

How is it that the face sometimes flushes so suddenly? Because of some emotion, you say. But how does the emotion bring this about? We have already learned about the muscles in the wall of the arteries. We are now prepared to understand that in the normal condition nervous impulses are acting on these muscles, keeping them partly shortened, and so keeping the arteries of a moderate size. Under the influence of certain emotions, the caliber of the arteries is suddenly enlarged, and hence the change in color.

**Effect of Exercise on the Size of the Arteries.** — As there is only a certain amount of blood in the body, it is evident that if one organ receives an extra supply, some other organ or organs must, for the time, receive less. For instance, one begins to walk vigorously. The large muscles of the lower limbs and trunk become active, and they need more blood. They therefore send messages to some nerve center (probably in the spinal cord), and by reflex action (a return message) the arteries supplying the lower limbs are widened, and these muscles receive more blood. But these muscles make up a very considerable part of the weight and bulk of the body. While in action, they take the lion's share of the blood. The brain, at such a time, would receive less, and it would be folly to expect the brain to work at its full capacity while the blood was called away to other organs.

**Effect of Temperature.** — A piece of ice is laid upon the skin of the hand. The part becomes pale, as the arteries have become narrowed. If this action be continued, there may set in a decided reaction, and the part become more red than usual, when the reaction has widened the artery more than it was before the constriction.

**Exercise also affects the Heart.** — When we exercise vigorously, the heart beats faster, and this of itself would tend to quicken the blood supply to all organs. But the mechanism for widening the channels leading to the working organs while the arteries to the other organs are not enlarged, solves the problem of supplying each part according to a greatly varying need, while not sending too much to a part not needing it.

**The Regulation of the Size of the Arteries.** — Through the sympathetic system the blood supply of all the organs of the body is regulated. Any organ needing more blood sends a message (nerve impulse) to some nerve center, and in response nerve impulses are sent to the muscle fibers of the supplying artery, and the amount of blood sent to that organ is regulated.

**Vaso-constrictor Nerves.** — In an experiment with a rabbit's ear it has been shown that stimulating the sympathetic nerve in the neck causes the ear to become pale. This is due to the constriction of the arteries of the ear, because the nerves have made the muscle fibers of these arteries shorten. Such nerve fibers are called *vaso-constrictor* nerves. They run in with the sympathetic nerve, but have their origin and center in the spinal bulb.

**Vaso-dilator Nerves.** — Other nerve fibers may cause the opposite effect, namely, dilation, and are therefore called *vaso-dilators*. Examples of these may be found running to the arteries of the limbs. When the muscles of any organ,

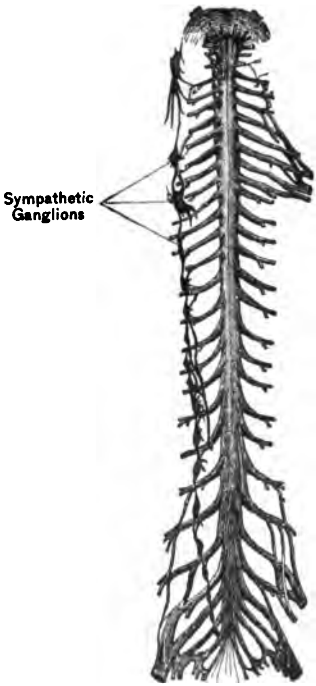



Fig. 45.—Ventral view of spinal cord with sympathetic ganglions of one side.

say the legs, act, they need a greater supply of blood. Now, at the same time that nerve impulses are sent to the muscles of the legs to make the muscles shorten, impulses are sent along other fibers of the same nerves to make the arteries dilate and allow more blood to flow to these muscles. The vaso-constrictor and the vaso-dilator nerves taken together are called *vaso-motor nerves.*

**The Sympathetic Nervous System.** — The sympathetic nervous system consists of two rows of nerve centers in the body cavity, one along each side of the spinal column, receiving branches from the spinal nerves, and sending branches to all the internal organs of the body—the heart and lungs in the thorax, and the stomach, intestines, and the other organs of the abdominal cavity. In many places these nerves form a thick network, called a plexus. One very large plexus is on the dorsal surface of the stomach, and is called the solar plexus. (See Figs. 45, 46, and 47.)

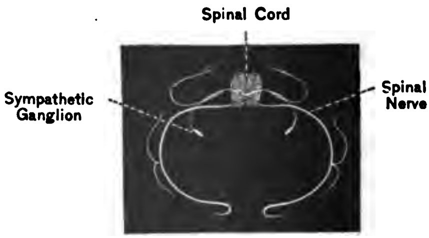



Fig. 46.—Ideal cross-section of the nervous system. (After Landois and Stirling.)

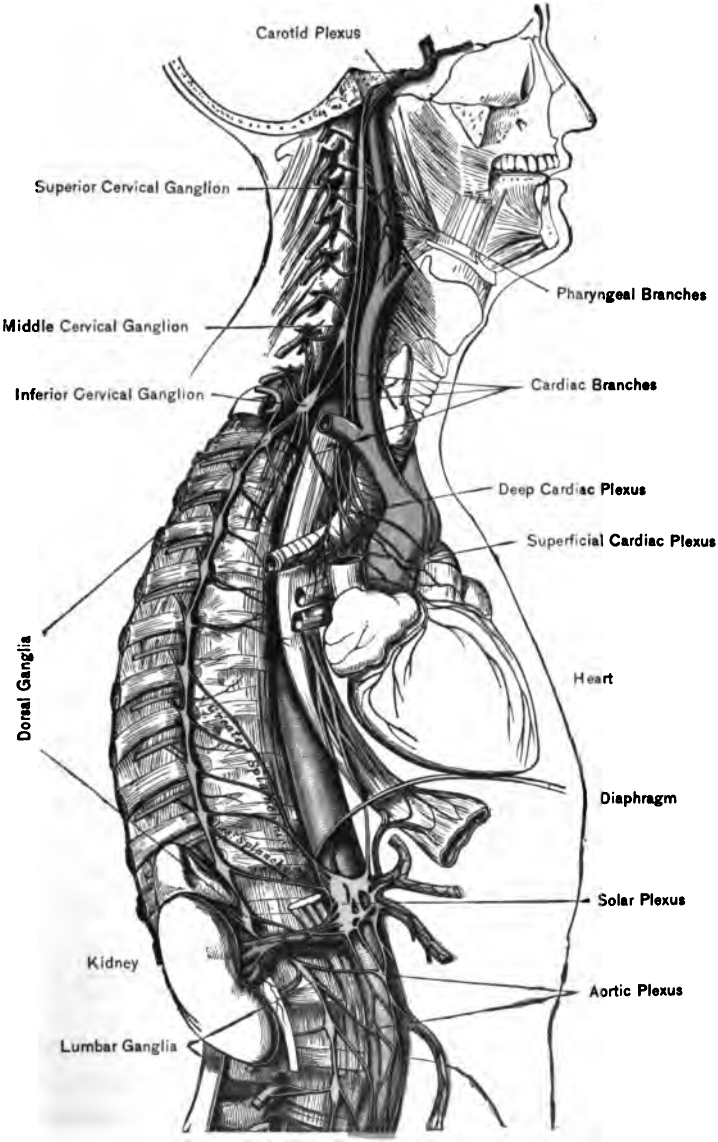



**Fig. 47.—Vertical section of body, showing sympathetic nerves and ganglia of right side and their connection with the cerebro-spinal nerves**

**Application of Vaso-motor Mechanism to Daily Experiences.** — We are now in position to understand and explain such common experiences as feeling sleepy while the back is turned to a heater, and not being able to get to sleep when we are cold, as heat affects the arterioles of the skin through the sympathetic nerves. We can also understand how chilling the skin may cause *congestion* in the arterioles of the lining of the nose (cold, or *rhinitis*); in those of the stomach, inducing a catarrhal condition; or in the tiny arteries of the lungs; how the nausea-producing remedies may relieve a "cold on the chest," that is, a gorged or congested condition of the arterioles or capillaries in the inflamed parts. Coughing is nature's way of raising the sticky mucus secreted by the inflamed tissues, and the inflammation — practically a local fever — is caused by poisonous waste products accumulated in an organ too long congested.

With our knowledge we can now see how, the skin being thoroughly chilled, the blood is kept out of it, and that some internal organ is gorged with blood, causing a "cold." This congestion will continue unless we get the blood to circulate freely again in the skin, by hot drinks, rubbing, vigorous exercise, or a sweat bath. Drugs should never be used unless prescribed by a physician. Most "cold remedies" contain a powerful laxative or an emetic; the first causing vaso-dilation in the walls of the intestine, and the second causing the same condition in the walls of the stomach, designed to relieve the excess of blood in the congested organ.

Every cold taken weakens the organ inflamed and may affect the whole body. The organ affected is more successfully attacked by germs; *e.g.* the lungs by pneumonia or tuberculosis, the intestines by typhoid fever germs, the

sore throat by diphtheria or scarlet fever germs. An ideal vaso-motor mechanism of the skin to prevent colds should act automatically, and this it does if one is in good health. When the skin is chilled for a time, the circular muscle fibers

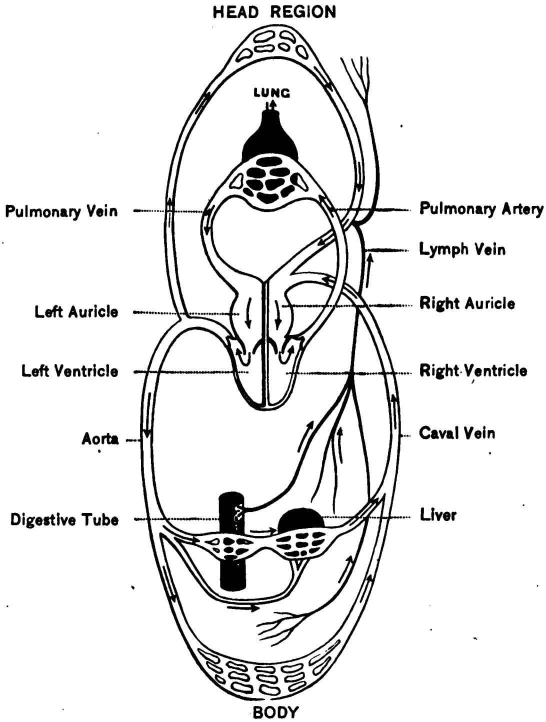



Fig. 48.—Plan of circulation. (Seen from back.)
In learning to copy this diagram it is better to begin drawing the heart first

in the arterioles are contracted; relaxing again, they allow an increased flow of blood which brings heat.

It is said that the vaso-motor system may be strengthened, *i.e.*, made to act more promptly and vigorously, by exercis-

ing it. This is done by alternately chilling and rubbing the skin, as in a cold sponge or shower bath.

**One Circuit of the Blood.** — Now the blood circuit is completed, since the arterioles empty into the more numerous, thin-walled capillaries, the walls of the capillary tubes being merely a continuation of the thin lining of the arterioles. A circuit of the blood is completed in about 30 seconds; for example, from the finger tip up through the veins, the heart, the arteries, and capillaries back to the finger tip.

Diseases peculiar to the blood or conveyed by the blood are discussed in Chapter XVI.

**Transfusion of Blood.** — Transfusion of blood is the transfer of blood from the blood tubes of one animal to those of another. Soon after the discovery of the circulation of the blood the operation of transfusion began to be practiced, and high hopes were indulged in as to its value. But it was soon found to be attended by so much danger that it is now seldom used. In the earlier practice lamb's blood was employed, but now when transfusion is practiced on man, only human blood is used. It has been found safer and better, after great loss of blood from hemorrhage, to introduce a salt solution of about the natural degree of saltness of the blood; this restores the normal volume of circulating liquid, and avoids most of the dangers except that of introducing air.

## Effects of Alcohol on the Circulation

The continued use of alcoholic liquors frequently causes what is known as "fatty degeneration" of the heart. The muscle cells are more or less replaced by fatty tissue, thus greatly weakening the heart. Experiments show that the first effect of alcohol on the heart is to weaken the force of the beat, though the rate is usually quickened. This indicates a deadening effect, such as is often seen in disease.

"The warm and flushed condition of the skin which follows the drinking of alcoholic fluids is probably, in a similar manner, the result of an inhibition of that part of the vasomotor center which governs the cutaneous arteries."[1]

The control of the muscles in the walls of the arteries being thus interfered with, the circular muscles are no longer made to shorten, and the artery dilates, thus allowing more blood to flow into it.

We may thus account for the flushing of the skin of the face, which in many individuals quickly betrays indulgence in alcoholic drink. If this flushing is too often repeated, the arteries gradually "lose tone," and the condition becomes permanent. The circulation in the whites of the eyes may be affected, making them "bloodshot." Permanent red nose and cheeks also result.

Similar congestion occurs in the mucous membrane of the stomach from the presence of alcohol, and this may become a permanent inflammation followed in time by very extensive changes in appearance and function. It is said that most of the alcohol swallowed is absorbed directly from the stomach, and hence the intestines are not so directly affected.

Good authorities state that alcohol arrests the development of the corpuscles. It diminishes the size, alters the form, and reduces the number of the corpuscles. Since the work of the blood corpuscles is so important, this reduction in their number and efficiency must very appreciably affect the nutrition of the body as a whole. When the blood is "out of order," the body is out of order.

For directions about stopping the flow of blood from wounds, see Chapter XVII.

[1] Foster.

Read in *Pathfinders of Physiology*, Appendix, the story of William Harvey, the English physician who established the fact of the circulation, 1628.

## QUESTIONS FOR REVIEW

1. Of what use is a knowledge of the blood?
2. What is the relation between lymph and the tissue cells?
3. Why is it necessary that lymph and blood should circulate?
4. What action have valves in the circulation?
5. What benefit is conferred by massage?
6. How is the lymph collected and returned to the circulation?
7. What is the source of lymph?
8. What are three kinds of vessels carrying red blood?
9. What makes blood red? What are the oxygen carriers in the blood?
10. Of what use is iron in the blood?
11. What are the blood scavengers? How do they keep the body from harm?
12. How were they discovered? What other uses have they?
13. How is clotting of blood brought about?
14. What are the chief uses of the plasma? What is its antigen function?
15. How are veins formed? Why do veins need more valves than arteries?
16. How are vaccine and antitoxin used?
17. Where does blood go from the right auricle? How does it get to the left auricle?
18. What change has taken place in the blood while passing from right ventricle to left auricle?
19. What valves does the blood pass in the heart? What is their action?
20. What vessels carry blood from the heart?
21. Compare the work time and rest of the heart. What is the cause of contraction of the heart?
22. How is the rapidity of contraction regulated?
23. How is the amount of blood sent to an organ regulated?
24. Where else does this mechanism come into play?

25. How do exercise and emotion affect the circulation?
26. How may our resisting power to colds be increased?
27. How is a mustard plaster effective?
28. Why are the feet often cold after studying?
29. Why should the clothing be changed after getting wet?
30. How many heartbeats for one circuit of the blood (calculated)?

## EXERCISES

*The Circulation of the Blood.* — 1. Evidences of the pumping of the heart: (*a*) Lay the fingers on the temples to feel the slight throbbing of the temporal artery. (*b*) Feel the pulse, the radial artery, on the wrist in the little hollow near the base of the thumb. While feeling your pulse with the right index finger, (*c*) feel the carotid artery at the left side of the wind pipe with the left index finger. How can you account for the slight difference in the time of their beat? (*d*) Feel the heart at the left of the lower end of the breast bone, between two ribs. Compare the time of its beat with that of either of the arteries already found. What effect would the distance from the heart have?

2. To get your average number of heartbeats per minute: Let some one give the signal for the beginning and the end of a minute by a watch, saying, "Ready, start"; and at the end of the minute, "Ready, stop." All students are to take three counts but to keep only the average of the last two. Compare the number of heartbeats with the number of breaths per minute.

3. To see blood in some of the organs: Hold the hand before a bright light with the fingers close together. If the light is properly screened in daytime, or the hand held very close if viewed in the evening, it is surprising how translucent and bright red the fingers appear.

4. To see red (colored) and white (colorless) corpuscles: If there is no microscope, then the first part of this exercise may be done to see the color and coagulation of blood. Tightly wrap a twisted handkerchief twice around the second joint of the thumb or finger and bend the finger. Place a large drop of saliva from the mouth on the joint and prick the skin through the saliva with a sterile pin. Mix the blood as it oozes out with the saliva and rub a little on a microscope slide. Place a cover glass on the smear and examine with

the low power, then with the high power of the microscope. The saliva keeps the red corpuscles from becoming distorted. How does a transverse view of the red corpuscles compare with the side view? What is striking about the color of the red corpuscles? You will be fortunate if you see any movement of white corpuscles. By what characteristics can you tell them?

5. To see the corpuscles moving in the capillaries: If a microscope is at hand, wrap a small gold fish loosely in a wet piece of clean cloth, leaving the tail projecting. Lay him in a shallow glass dish with a little water in the bottom; a piece of glass will do if there is no such dish at hand. The tail is now placed under the low power of the microscope and kept in focus. This is necessary because the fish will attempt to move the tail, and on this account it will be better also to lay a glass slide on top of the tail. This will not interfere with the use of the low power. The plasma is too transparent to be seen.

# CHAPTER VI

## NUTRITION

**What Nutrition Is.** — Much of what is discussed in this chapter cannot be seen or described in the ordinary way, or told from the examination of objects.

We are now to follow in imagination the liquid nutrients — sugar, proteins, and fats — after absorption through their changes among all kinds of cells in the body: forming new cells in our growing period; renewing[1] those worn out; supplying material for the activity of working cells; and finally giving heat to keep us warm.

Sometimes nutrition is defined as, " All the changes that nutrients undergo from the process of absorption to the excretion of waste substances." This includes *assimilation*, the building of food into new tissues, and *oxidation*, the consumption of food to give the tissues energy.

**Changes in Nutrients during Absorption.** — The fats are broken up in digestion into the soluble fatty acids and glycerine. These are afterward recombined, probably in the walls of the intestine, and with the alkaline lymph form an emulsion or milky-looking mixture that is carried to the lacteals through the thoracic duct and thence into the veins.

NOTE. — When excess of sugar is eaten, some may get into the circulation by the same route and be carried to the kidneys, doing harm. Likewise after excess of meat food some protein may be absorbed by the lacteals and do harm in the circulation. Observance of the diet table (see page 29) will help to avoid these evils.

[1] It was formerly a popular belief that the body is rejuvenated once in seven years, the tissues being worn out and rebuilt in that time. This belief has no scientific foundation.

The digested proteins are likewise changed in the walls of the intestine into the proteins suitable to be carried in the blood, *serum albumin* and *globulin*. These and the simpler sugars resulting from the digestion of starch are now carried by the portal vein to the liver and spread through all its cells. Here in the liver cells the first important work of *metabolism* is performed.

**Preliminary Stages of Metabolism in the Liver.** — After digestion there is more sugar in the blood than before taking food.[1] But the liver cells take the excess of sugar from the blood and change it to another carbohydrate suitable for temporary storage in the liver. This storage product is named *glycogen*.[2] It is believed to be made from the sugar by a ferment.

Immediately after absorption a new change begins, and the liver cells slowly break down the glycogen into sugar and give it to the blood to keep constant the percentage of sugar in it. The importance of this function of the liver is shown by the discovery that when too little carbohydrate food is taken, and even during starvation, the liver manages to give the blood the proper percentage of sugar.[3] In this case it is supposed to send out ferments which break down normal tissues to get sugar for the blood. Indeed, the liver

[1] Normally the arterial blood has from 1 to 2 per cent of sugar, which is used in the muscles. More than this is harmful in the blood.

[2] In many lower animals glycogen is present as stored food. In clams and oysters it forms a rod in the digestive tract.

[3] Other cells, chiefly those of the muscle tissue, also help to keep a constant percentage of sugar in the blood, by converting it into glycogen and storing it as the liver did. This then acts as a local reserve and can be drawn on in case of need. In fact, it is said that there is a constant interchange from glycogen into sugar for use, and from sugar into glycogen for storage. This is an important factor in the equalization of sugar in the blood and is under the influence of the liver.

can make fat and glycogen out of the carbon, hydrogen, and oxgyen of protein. (See Composition of Protein, page 12.)

**What becomes of Protein Food.** — Assuming that the digested proteins are combined in suitable form for circulation, the liver cells [1] again take out of the blood all excess of protein not needed for tissue building in the body. This excess of protein is separated into (1) a nitrogenous part similar to ammonia, and (2) a non-nitrogenous part which is afterward oxidized or built into fat and glycogen. The ammonia part is further changed into *urea* — the nitrogen waste that is regularly excreted in the kidneys.[2] This separation is the work that the liver has to do on the excess of protein in our food beyond that needed for tissue building and repair.

**Source of Muscular Energy not Proteins.** — Since muscles are the engines of motion, and also are largely composed of protein (nitrogen-containing) material, we would naturally expect that increased muscular exertion would increase the excretion of urea (the only nitrogen-containing waste). But experiment shows that increased muscular action, such as mountain climbing, hardly increases the amount of urea excreted. Such work, however, does largely increase the amount of carbon dioxide excreted. It is thought, therefore, that our energy is largely derived from carbohydrate foods and fats, and this view is strengthened by the fact that our beasts of burden depend chiefly on carbohydrate foods.

While increased muscular action does not very per-

[1] There is still a difference in opinion among physiologists whether the digested proteins are recombined in the walls of the intestine or in the liver.

[2] In fact, urea is the nitrogen waste formed wherever cells in the body are active.

ceptibly increase the amount of urea excreted, an addition to the amount of protein food taken does increase the amount of urea.

**Destination of Tissue Protein.** — What has so far been said does not mean, finally, that there is no loss of protein from muscle tissue. In fact, each muscle cell makes or secretes a ferment which changes the stored glycogen into sugar to be returned to the blood, or for oxidation outside the cell. Now this secreting is done at the expense of some protein material in the cell, and this must be repaired or the cell built up again by tissue-building protein.

In *gland cells* the work is entirely secretory, *i.e.* the glands form secretions such as the digestive juices, the mucus, etc., from the proteins in the blood. After taking necessary material from the lymph, in the same way that all cells obtain their nourishment from the lymph, the gland cells make out of it their particular secretion, building it up into their substance usually in the form of solid granules. This is one form of assimilation. The granules can be seen under the microscope.

When the gland cells act, the granules disappear, forming the secretion peculiar to the gland named. The gland cells are reduced in volume after action, and during their needed rest are again built up. For this building up, protein material is necessary.

**Growth and Repair.** — Leaving out of account the number of cells calling for tissue-building protein in our food — as in that of all growing animals — while we are young, certain processes in our bodies call for new cells.[1] One of these is the sloughing or rubbing off of dead cells of the

[1] Protein alone can be used for tissue repair; carbohydrates and fats serve for energy supply.

*epidermis*, or outer skin. They are as constantly replaced by new ones, grown in the under layer of the epidermis, the nourishment for this being drawn from the lymph in this layer. Again, nails — the claws of animals — and hairs are growing throughout life, and thus call for new cells to be made from tissue protein. Red and colorless corpuscles are constantly grown anew in glands, in the red marrow of the bones, etc. Finally, protein is needed where wounds heal by a process of cell growth, *i.e.*, by an increase in number of cells until the wound is healed.

By growth is understood increase in number of cells of all tissues and organs, and increase in their bulk, until our organs have attained full size in adult life, at about 23 years of age. In this connection it is to be remembered that certain mineral salts are necessary in our foods and that all nutrient liquids in the body must contain them. These are necessary not only for the proper work of the cells, but some of the lime salts, such as the carbonate and phosphate of calcium, are largely used in the building of bones and teeth.

**Fats.** — When much more food is taken than is needed, especially of fats, sweets, and other carbohydrates, the excess is made into fat and stored up in the connective tissue under the skin and elsewhere. This tissue fat serves as a stored-up food. The camel's hump is a well-known instance. In some of the savage races fat is stored in a very similar hump. But in most persons it is distributed more evenly over the body, though there is a tendency to deposit rather more over the abdomen. A fat person can endure starvation longer, other things being equal, than a thin person. A layer of fat under the skin serves also as a heat saver.

NOTE. — Hibernating animals are fat when they enter upon their winter sleep, but are lean when they come out in the spring. Remaining inactive, they have produced very little energy, their only motions being a slow and feeble breathing and a correspondingly reduced heartbeat. They have consumed the fat, using it mainly in maintaining the necessary heat. In short, they have burned their fat to keep them warm.

There is some evidence to show that protein may be changed into fat and glycogen. When fat is again needed, it is drawn out of storage, and by certain *enzymes* formed in cells, it is dissolved so that the blood can absorb and carry it to the tissues where it is needed. It is generally held, however, that fat nutrient is especially for heat production, while carbohydrates alone serve for the production of muscular energy.

**How and where Oxidation Takes Place.** — The popular belief that we breathe oxygen to burn up waste matter is a mistaken idea. Ashes cannot be burned again. At one time it was held that food material was built up into the protoplasm of the cells, and by oxidation[1] (internal respiration) was broken down to furnish energy. Later teaching was that the nutrient material was oxidized *in* the cells but without having been built up into the substance of the cell. According to this view oxidation was not merely a mechanical process of " touching off " a charge as you might ignite gunpowder. It was rather a vital process, the oxygen uniting with the nutrient material under the influence of the living protoplasm.

*Now* this later view has been modified in one point by newer

[1] The oxygen was also supposed to be conveniently stored in the cells, somewhat as it is in gunpowder. Nerve impulses to the cells caused the oxidation and discharged the energy. All our bodily activities were supposed to originate in this way.

investigations. Accordingly, it is held that while the cell, as living protoplasm, takes in oxygen and gives out carbon dioxide and water, the oxidation of nutrient material does not take place in the cells, but in the lymph *around* the cells.[1]

**Energy in the Body.** — In the chapter on Foods and Their Uses, much was said about food for strength, or energy, and for heat. It was made evident that nutrients, when burned outside the body, as in the calorimeter, give off no more heat than when burned slowly in the body. It was also stated that heat results from slow, as well as rapid, oxidation. Now heat is one form of energy, as work can be done by means of heat; for example, the expansive or working force of hot air and steam, in engines of corresponding kinds. The oxidation of foods in the lymph around the muscle cells transforms the energy in food and oxygen into muscular energy which enables the muscles to do their work. Two kinds of energy are commonly spoken of in the body — muscular energy and heat energy.

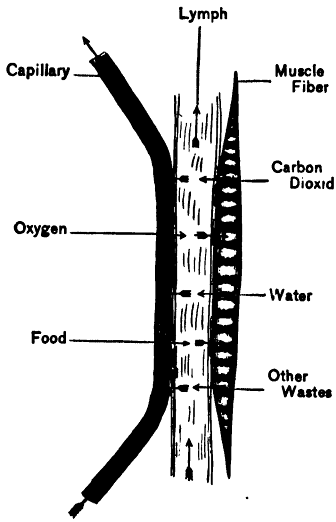


Fig. 49. — Relation of blood and muscle
(Lymph being middleman.)
Greatly magnified

[1] The nerve impulses are then to be looked upon as causing and *regulating* energy release. They may increase or decrease the rapidity of oxidation. Indeed, all the assimilative and oxidative processes (*metabolism*) in our bodies are believed to be under the influence of the sympathetic nervous system.

**Sources of Body Energy.** — Since heat and muscular energy arise from the oxidation of food, and since the combining of oxygen with the elements of nutrients merely liberates these energies, it is evident that the energy must have come into the body with the food material. After food matter is oxidized, it is no longer food, but the chemical elements composing it are not destroyed. Some are used immediately and some are reconverted into new food with stored energy. This may be seen from the following considerations.

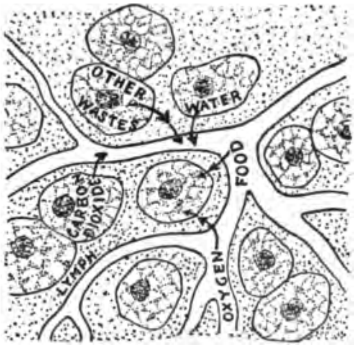



Fig. 49*a*. — Cells and capillaries

Showing capillaries branching among the cells, and the interchange of food and wastes

**Elements of Matter are never Destroyed.** — In the continual wasting away of our bodies there is no real loss

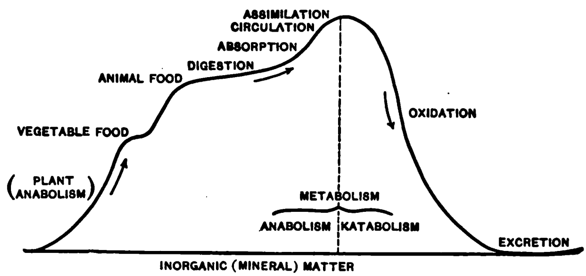



Fig. 50. — Life processes

Plants build up and animals tear down, or use up food

of matter. Our weight is reduced, but the wastes are still part of the earth or air, and are used again. For instance, a particle of carbon in the carbon dioxide of the expired

breath may be taken in through a blade of grass in an adjoining field. A cow may eat the grass, and we may soon take the very same particle of carbon in the flesh or milk of the cow. Or the carbon may be taken by that kind of grass called wheat, and become part of the seed or grain of wheat, and be made into flour and be eaten as bread and be part of us once more. Or this particle of carbon might be carried by the winds to Florida or California, and be-

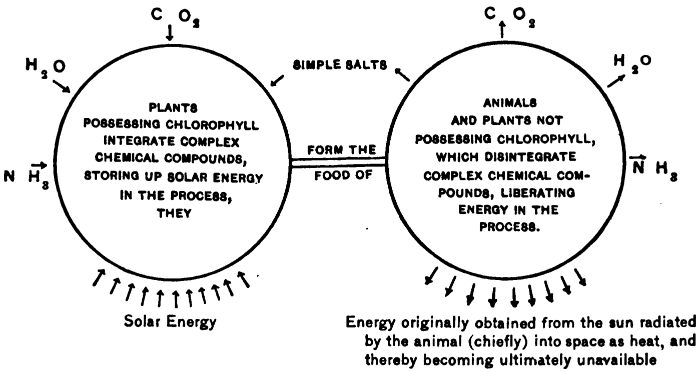



Fig. 51. — Relation of plants and animals

come part of an orange, and come again to make part of our bodies. Thus there is a ceaseless round of matter into and out of our bodies. The plants furnish food for us, and we help to make food for them by the wastes of our substance. No one has a monopoly of any portion of matter; it is now ours, now some one else's. A particle may pass from one animal to another animal, as when we eat flesh or other animal food. But more often the wastes of our bodies go to make part of the air or the soil, and are then taken by some plant before again becoming part of our tissues. We are as unable to destroy matter as we are to create it.

We are agreed then that we cannot destroy matter. We may demolish a house, but the material is all there. We may burn it, but if we could gather the ashes and that part of the smoke and gases furnished by the material of the house, the weight would all be recovered.

**Energy is not Destroyed.** — We cannot create energy and we cannot destroy it. We derive our energy from the food that we eat. And this food we get directly or indirectly from the vegetable kingdom.

An engine gets energy from the combustion of fuel. In the growth of the plant under the influence of sunlight the plant has stored energy. When the wood or coal is burned, the energy is given out, primarily as heat. But we may convert the heat into electricity, the electricity into light, or back again into heat if we wish. We get our energy from food as the engine gets its energy from fuel. This is saying nothing against the superiority of the human body, and is not in the least degrading. We are self-maintaining, self-directing, growing, living machines. Still, starvation soon puts an end to our ability to produce energy of any kind.

**The Utilization of Energy in the Body and in Machines.** — It is a well-recognized fact that in very many machines only the smaller part of the energy is directed to the end sought. Take a common candle. We wish to get light from it. But most of the energy of the candle is devoted to making heat, which in this case we do not desire. In many machines there is great loss from friction, from radiating heat, or in other ways. Physiologists tell us that the human body utilizes a larger portion of its energy than most machines. While energy may fail to be used for the desired purpose, it is never destroyed nor really lost.

## Correlation and Conservation of Energy

1. *The Correlation of Energy.* — All kinds of energy are so related to one another that energy of any kind can be transformed into energy of any other kind.

2. *The Conservation of Energy.* — When one form of energy disappears, an exact equivalent of another form of energy always takes its place, so that the sum total of energy is unchanged.

These two principles constitute the corner-stone of physical science. They must be kept in mind if we would understand the actions of our bodies, our relations to the surrounding world, to the universe in which we live and of which we must consider ourselves a part.

### QUESTIONS FOR REVIEW

1. What two processes does nutrition include?
2. How do fats get into the circulation?
3. Through what organ do the absorbed protein and sugar pass?
4. What changes may take place in each of these nutrients before being given to the blood again?
5. When and how is the carbohydrate used? What is its name? What other animals store it?
6. What is the chief proof that muscle tissue does not break down to furnish contractile energy?
7. What becomes of the excess of protein nutrient eaten?
8. What use is made of the normal protein food in the blood?
9. In what ways does the protoplasm of cells need building up?
10. What processes call for new cells?
11. Of what uses are the fats in the body?
12. What nutrients can replace each other?
13. Which one cannot be replaced by the others? Why?
14. What was formerly taught concerning oxidation in the tissues? What is the present teaching?
15. What are the kinds of energy in the body?

16. How are these energies liberated — not made?

17. What is meant by the statement, "Matter cannot be destroyed"? Illustrate your answer.

18. Can energy be made anew? Can it be destroyed?

19. What is the principle expressing this?

20. What relation exists between the different kinds of energy in the universe? How is this expressed?

# CHAPTER VII

## THE RESPIRATORY SYSTEM

**Breathing.** — Every live thing breathes. This is as true of plants as of animals; true, indeed, of that primary living substance — protoplasm. The single-celled ameba, crawling slowly, without definite shape or separate organs, has as much need of breathing as the highest animal, or man.

In many lower animals, such as the earthworm, breathing takes place through the skin, there being no other breathing organ. This is frequently the case in animals that always live in moist earth, and in minute organisms which live in water. But in most aquatic animals — from worms to fishes — there are gills. Water snails have gills while land snails have lungs, and in Africa, Australia, and South America there is a kind of fish which has both gills and lungs. These are called "lungfishes," and they are able to live in wet mud through a season when the streams and lakes of their usual home become dry. Insects, on land and in water, have breathing tubes, and spiders carry their "lung books" with them.

**External Respiration.** — In both terrestrial and aquatic animals, the main object of external breathing is to bring oxygen to the blood and to remove waste gases from it. The oxygen from air or water goes into the blood, attracted by the *hæmoglobin*, which has little oxygen. The carbon dioxide goes from the blood, where there is much of that gas, to the air or water, where there is less.

**Principle of Diffusion of Gases.** — This change of gases takes place rapidly, according to a principle that a gas passes readily through a thin moist membrane, in the direction where there is less of that particular kind of gas. The walls of capillaries, lungs, and gills are such moist membranes.

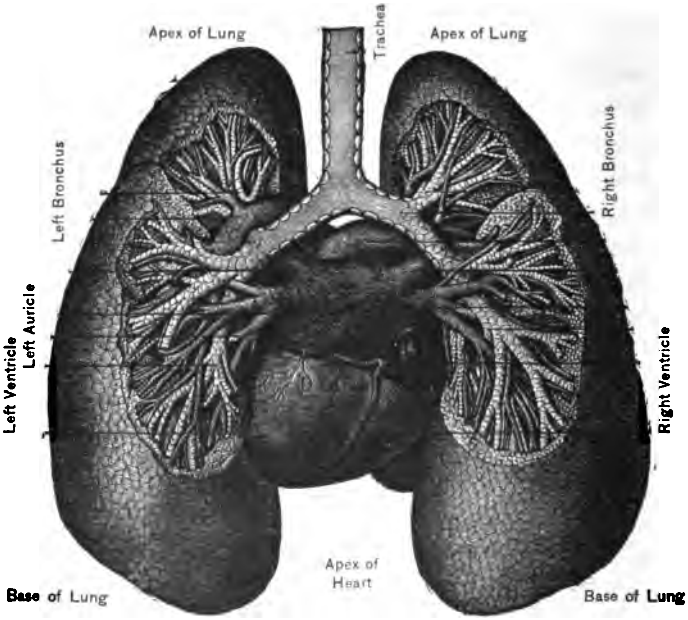



Fig. 52. — Heart and lungs seen from the back

Notice the incomplete cartilage rings on the trachea and larger bronchi, also the air sacs (alveoli) showing through the surface

**Lungs and Air Vesicles.** — The lungs are merely reservoirs for holding the air during the exchange of gases between the blood and the air. In man, the lungs are two sac-like bodies in the upper part of the chest. They occupy nearly all the space not taken up by the heart and blood vessels. To better serve their purpose of exchange of gases, they are

completely honeycombed with minute air sacs (Fig. 52). The air sacs, in turn, are the chambers into which open a great number of smaller air vesicles, no larger than a pin-head. So numerous are these vesicles that the number in the lungs of an adult is estimated to be 700,000,000, and their surface, if spread out side by side, would cover more than 2000 square feet.

The air sacs are the expanded, closed ends of the smallest branches of the air tubes, the *bronchioles*. Each air sac is

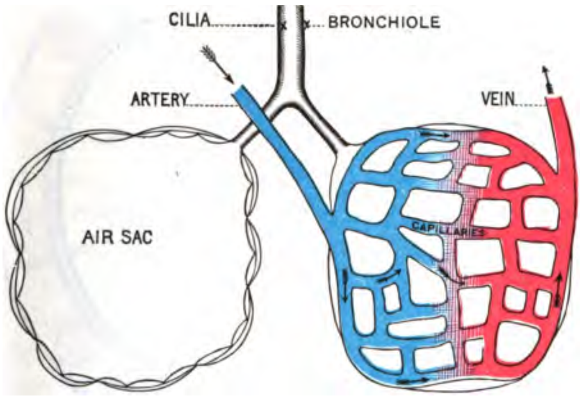



**Fig. 53. — Minute structure of the lungs, showing air vesicles and capillaries**

completely enveloped by blood capillaries where the blood is spread out over this large surface for the exchange of gases, thus making the air sacs the most important part of the organs for external respiration.

**Accessory Breathing Organs.** — After the air has given up its oxygen and received carbon dioxide, it must be exchanged for fresh air, and this is the work of the accessory breathing organs such as the air tubes and structures which increase and diminish the size of the chest, principally the diaphragm and the muscles acting on the ribs.

**The Air Tubes.**— These are the *trachea* (or windpipe) and its branches. The trachea opens at the back of the mouth and extends five or six inches downward, where it

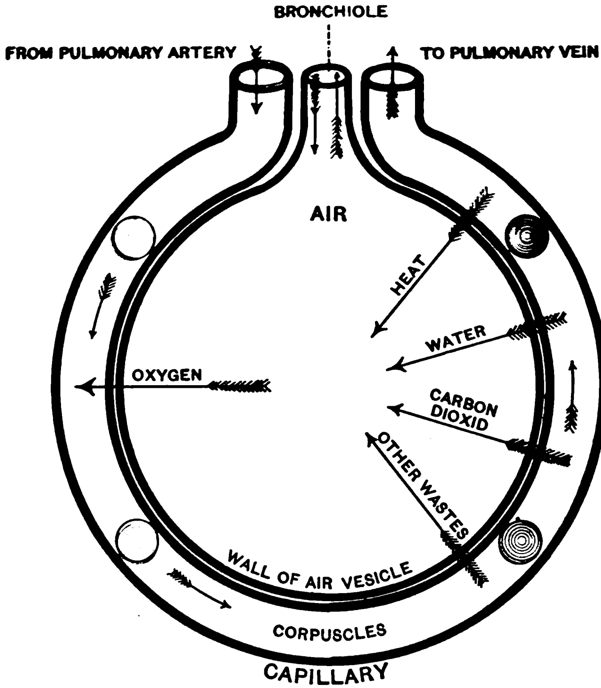



Fig. 54. — Exchanges between the air and the blood in the lungs

divides, sending one branch to each lung. The branches are the right and left *bronchial tubes*, and these subdivide into a great number of smaller tubes, the *bronchioles*. All the air tubes stand open day and night, so that the air may pass in and out freely.[1] (See Fig. 55.)

[1] The only exception is momentary, while we are swallowing. (See Figs. 17 and 18.)

They are held open by cartilage, *i.e.* gristle, rings, and plates in the lining of their walls. In the trachea the rings are C-shaped, with their opening at the back, where the food tube lies close to the windpipe. These cartilages continue in the bronchi, and so on until in the smaller twigs they finally disappear. The cartilages are held together, and the dorsal gaps of the cartilages (see Figs. 52 and 55) bridged, by tough fibrous tissue, with much elastic tissue, and with plain muscle fibers; the plain muscle fibers are very abundant in the smaller air tubes. At the upper end of the trachea there are other and larger plates of cartilage which form the voice box, or *larynx*. (See Voice, Chap. XIV.) In the nose, likewise, there are cartilage plates to keep the air passage open at all times.

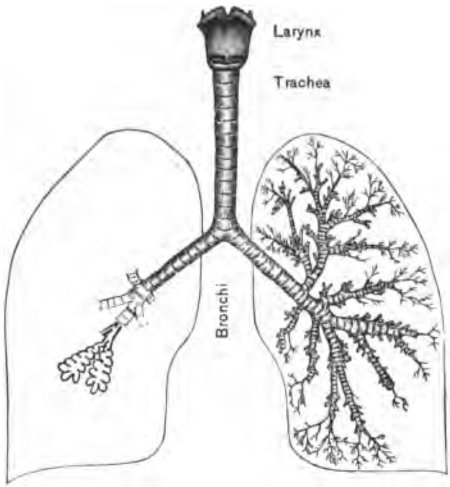


Fig. 55.—The trachea and bronchial tubes, showing two clusters (alveoli) of air vesicles

**Location of Mucous Membrane.** — All the cavities and passages in the body to which air has access, such as the digestive and respiratory passages, etc., are lined by mucous membrane. It pours out on its surface a substance somewhat like mucilage, called *mucus*. This keeps the air moist, and catches particles of dust that are in the inspired air.

**Cilia.** — Each of the cells that line the trachea and all its branches but the smallest sends up from its surface 20 or 30 slender, contractile, threadlike projections called *cilia.* Each *cilium* contracts, making a quick, strong stroke upward toward the mouth, and then relaxing, falls back. By this motion the cilia keep the secreted mucus moving upward to the larynx, where it may be removed by coughing.

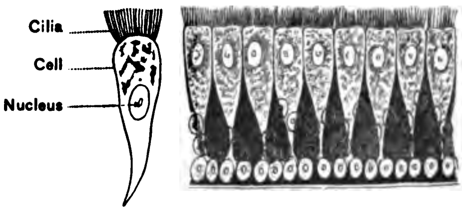


Fig. 56. — Ciliated cells lining the air tubes (× 300)

**Air Pressure and Breathing.** — It has been said, "We live at the bottom of a sea of air." The atmosphere, or the whole air surrounding the earth, is from 2 to 5 miles high, and though it is only air, it has weight and presses upon us. At sea level this weight is about 15 pounds on every square inch of surface. Air pressure keeps all spaces that are not otherwise occupied filled with air. So the lungs are filled, as an empty bottle[1] might be, by air pressure, and they are also forced against the inside of the chest walls, completely filling the part of the chest cavity not occupied by the heart and blood vessels.

**Residual and Tidal Air.** — This accounts for a certain amount of air, always present in the lungs. It is called residual air,[2] and cannot be breathed out. But it does not account for the change of air above called for, the *tidal* air, meaning that which comes and goes in *breathing*.

[1] By "empty" and "space" is meant filled with air.
[2] In drowning, residual air is replaced by water.

**Tidal Air.** — Let all breathe together, at the ordinary rate and depth, and let the hand rise about three inches during inspiration, and fall again during expiration. The amount of air taken in at an ordinary breath is from 20 to 30 cubic inches, or about a pint. This is called tidal air.

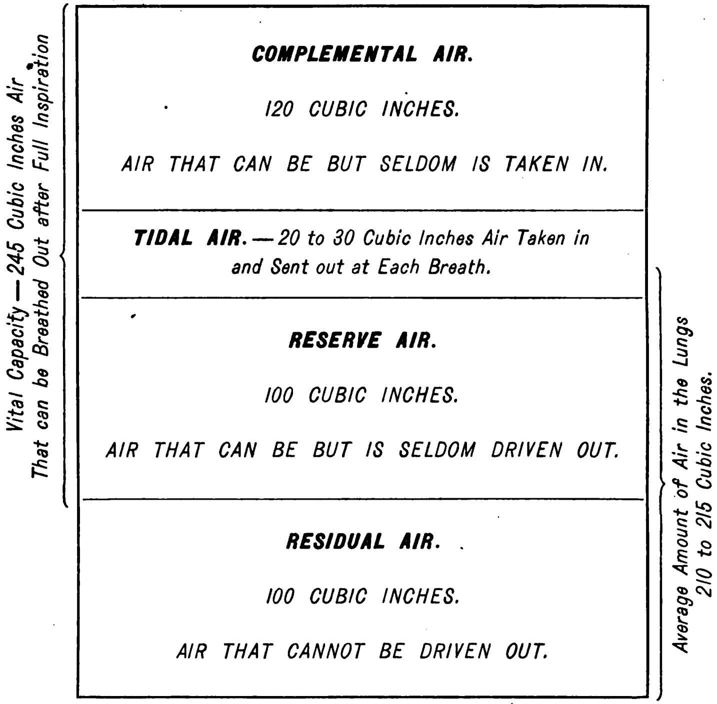



Fig. 57. — Diagram of lung capacity

**The Vital Capacity.** — All the air that can be breathed out after a full inspiration, breathing in as much as possible, would be about 240 to 250 cubic inches for an adult, and is called the vital capacity. Of course these figures represent only the average of certain experiments and observations. By practice any one can considerably increase his vital capacity.

**How Air is Inspired.** — In inspiration the principal active forces in the body are, first, the diaphragm; second, the muscles which elevate the ribs.

**The Diaphragm.** — The diaphragm is a thin muscle making a complete partition between the abdominal cavity and the chest cavity. It is convex above, concave below; its front border is attached to the inside of the chest wall about opposite the lower end of the breastbone, thence obliquely along the border of the ribs (as felt in front), and the attachment at the back is below the front attachment. Its general position is shown in Figs. 10, 47, and 58.

**Work of the Diaphragm in Inspiration.** — The diaphragm is a muscle, and when its fibers shorten, the diaphragm is pulled down. In moving down it presses on the abdominal organs, and makes the abdomen protrude laterally and ventrally. This lowering of the diaphragm increases the space in the chest; the air already in the chest expands to fill this greater space. When expanded, it exerts less pressure than before, and the air outside, having greater pressure, enters till equilibrium is produced. The air enters through the trachea, presses on the inside of the elastic lungs, and makes their bases extend, following the diaphragm in its descent. The bases of the lungs remain in contact with the upper surface of the diaphragm all the time. (Fig. 58*a*.)

**Effort required in Depressing the Diaphragm.** — Inspiration requires considerable effort, because the diaphragm in its descent presses upon the elastic organs of the abdomen (stomach, liver, etc.), and these organs, in turn, are pressed against the elastic walls of the abdomen. It is somewhat like pressing a pillow down into a rubber bag; the pillow springs up as soon as the pressure is stopped, because of its own elasticity as well as that of the bag. Therefore, as

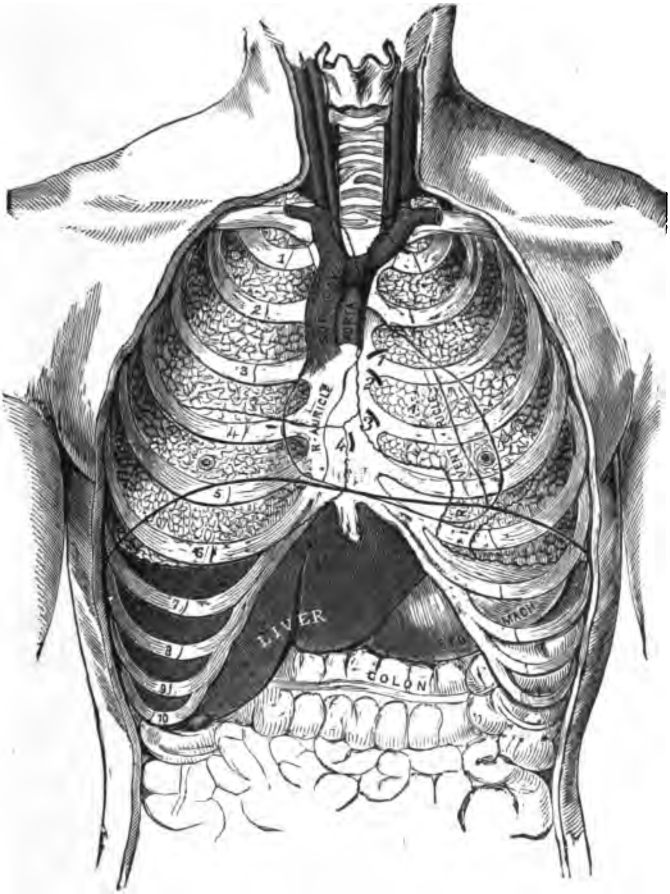



Fig. 58. — Front view of the thorax
The ribs and sternum are represented in relation to the lungs, heart, and other internal organs
**The heavy black line between the heart and the liver represents the diaphragm**

soon as the diaphragm relaxes, the elastic walls of the abdomen retreat, and the abdominal organs rise to their former place.

**Work of the Chest Walls in Inspiration.** — Certain muscles of the chest walls elevate the ribs and breastbone. This act widens the chest, and the air, as before, presses in through the open trachea, and keeps the sides of the lungs in contact with the inner surfaces of the chest walls.

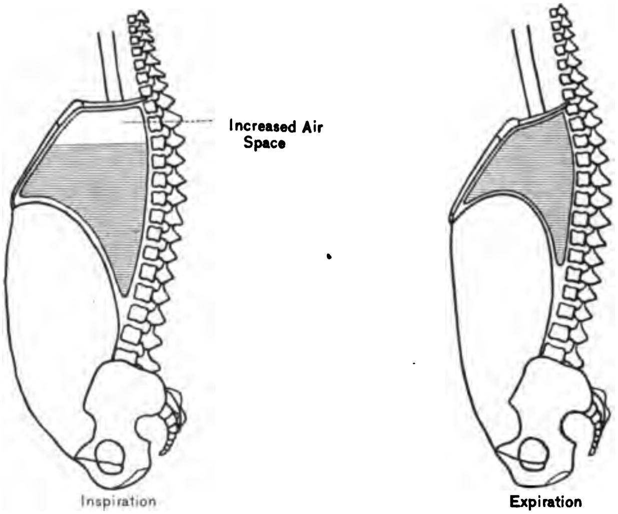



Fig. 58a. — Diagrammatic sections of the body in inspiration and expiration

When the ribs are elevated, the cartilages which connect the ventral ends of the bony parts of the ribs with the breastbone are slightly bent. When the muscles relax, the elasticity of the rib cartilages helps to bring the ribs back to their former position, thus reducing the chest to its former width.

**Expiration Easy.** — Thus we see why expiration is easy; in fact, it "does itself" (in ordinary respiration) by elastic reactions. But inspiration is harder than it would be if it were not for the fact that the descent of the diaphragm

meets resistance, and the ribs, in rising, have to overcome resistance in bending the costal cartilages, and in raising the weight of the chest walls and shoulders.

NOTE. — It is interesting to note that in birds the process is reversed. Their muscles do the work by compressing the body walls and these force the air out, and by elastic reaction of the body walls the air is again drawn in. Read in some Zoölogy how frogs and reptiles breathe.

**Mechanical Illustration of Expiration.** — When one opens a door that has a spring to shut it, he has to expend more energy to open the door than he would if he did not have to bend (twist or compress) the spring at the same time. But no effort is needed to shut the door. We can better afford to employ more energy while opening the door than to take the extra time to shut it. When released, it flies shut. If one, in this case, asks, "Who shut the door?" the answer is, "The person who opened it." So in the act of inspiration we perform a double work in storing energy by which the expiration is performed without active muscular effort.

## REVIEW OF FORCES OF EXTERNAL RESPIRATION

### *Forces of Inspiration*

1. Depression of the diaphragm.
2. Muscles elevating the ribs.
3. Pressure of the external air.

### *Resistances to Inspiration*

1. Compression of the abdominal organs and stretching abdominal walls.
2. Bending the rib cartilages and lifting the chest.
3. Stretching the lungs.

*Elastic Reactions to Expiration*

1. Elastic reaction of the abdominal walls and contents.
2. Elastic reaction of the rib cartilages.
3. Elastic reaction of the lungs.

**Abdominal and Thoracic Respiration.** — The main part of respiration is performed by the diaphragm, and the more common mode of respiration is therefore called abdominal or diaphragmatic respiration. In women of the civilized races respiration is more largely accomplished by the action of the thoracic muscles, and is called thoracic or costal respiration. In children the respiration is of the abdominal type.

**The Close Relation between Circulation and Respiration.** — Is it not a very striking fact that we take one breath for every four heartbeats? That whatever quickens the breathing also quickens the heart, so that the two always keep in almost the same ratio?

**The Rate of Respiration.** — The rate of respiration in the adult varies from sixteen to twenty-four per minute, the average being about seventeen times a minute — about one respiration for every four heartbeats. Light is favorable to respiratory activity. The rate is affected by the position of the body, state of activity, temperature, digestion, emotions, age, disease, etc. Ordinary inspiration takes slightly less time than expiration.

**Modifications of Respiration.** — Coughing is a forcible expiration, usually directed through the mouth, and for the purpose of getting rid of some foreign substance, or caused by irritation. In sneezing there is first a deep inspiration, and then the current of air is forced out, chiefly through the nose. Sneezing may be prevented by pressing firmly on the upper lip. Crying, laughing, and sobbing are modifications of respiration connected with certain emotions. Yawning and sighing are deeper breathings, caused by *ennui*, depressing emotions,

or deficient ventilation. Hiccoughing is sudden inspiration, produced by spasmodic action of the diaphragm, accompanied by sudden closure of the glottis, and is often caused by some disorder of stomach digestion. Snoring is caused by breathing through the mouth and setting the soft palate into vibration. Sniffing is sudden inspiration: the diaphragm is suddenly pulled down, the air in the nasal cavity is thus drawn downward, and the air we wish to test, or the odor we wish to inhale, is thus drawn into the upper nasal cavities; whereas in ordinary inspiration most of the air passes along the lower part of the nasal passage. In hawking, the air is forced out through the narrowed passage between the root of the tongue and the soft palate and removes mucus. Gargling is forcing air up through liquid held between the tongue and the soft palate. Panting, whistling, blowing, spitting, sucking, and drinking are also modifications of respiration. In case of choking it is well to hold the head forward, and perhaps downward. A smart slap between the shoulders sometimes helps to dislodge anything stuck in the throat, and it may be necessary, in addition, to hold a child with its head downward.

**Composition of Inspired and Expired Air.** — In the beginning of this chapter it was stated that the air receives carbon dioxide in the lungs and gives off oxygen to the blood.

Normal air is a mixture of the following gases: oxygen, 20.96 per cent; nitrogen, 79 per cent; carbon dioxide, 0.04 per cent. Expired air has the same amount of nitrogen, 79 per cent; but the carbon dioxide is increased a hundredfold, being 4 per cent, and the oxygen has been reduced from 20.96 per cent to about 16 per cent. Besides this the air is warmer by several degrees and contains much more moisture.

| | Oxygen | Nitrogen | Carbon Dioxide |
|---|---|---|---|
| Inspired air . . . . . . | 20.96 % | 79 % | 0.04 % |
| Expired air . . . . . . | 16.00 % | 79 % | 4.00 % |

**Amount of Oxygen Used.** — We take into the blood only about one-fourth of the oxygen of the air that passes through the lungs. In like manner, the blood, passing through the tissues, gives up to those tissues (in ordinary circumstances) only about one-half the oxygen that it contains, perhaps holding the remainder as a reserve. Sometimes we wonder why we breathe out three-fourths of the oxygen of the air and keep only one-fourth when we need oxygen so much. It is because the hæmoglobin cannot take more. And this remains true even if we should breathe very fast or breathe pure oxygen.

**Breathing Pure Oxygen.** — Pure oxygen is occasionally administered in cases of pneumonia. The lungs are then so clogged with mucus that not enough oxygen from ordinary air can diffuse into the pulmonary arteries to supply the needs of the blood. It was formerly believed to be dangerous to breathe pure oxygen since it was thought the tissues would be oxidized too rapidly. Breathing pure oxygen does not make one feverish, it does not produce any more heat, nor make one "live faster." This point should be specially noticed, as it was formerly supposed that the oxidation of the tissues of the body was just like the combustion of dead material. But the tissues are alive. *Each cell takes what it requires* and *no more*, just as it does of food brought to it by the blood. The amount of oxygen present does not determine the degree of muscular activity, but the degree of muscular activity determines the amount of oxygen consumed.

While a little oxygen is dissolved in the plasma and carried to the tissues in that way, the greater part is carried by the red corpuscles. It is an interesting fact that the oxygen of the red corpuscles combines chemically with the

hæmoglobin, making *oxyhæmoglobin*. Thus there is a preliminary oxidation and probably some release of energy. Increasing the number of red corpuscles in the blood, a good diet, regular out-of-door exercise, and constant breathing of fresh air aid in the exchange of gases in the lungs. Of these, proper exercise is believed to be the most essential.

**Two Kinds of Respiration.** — We have thus far followed the external respiration, have seen the adaptation of the special organs concerned in it, have noted how the structure of the lungs, the contraction of the diaphragm, the shape of the chest, and even the pressure of the atmosphere all work together to insure the fullest, freest, and most constant exchange of air in the lungs.

We may now well ask if this is the final purpose of respiration. Is all the delicate mechanism and the abundant means of oxidation merely for bringing the air to the blood in the lungs? What does the blood do with the oxygen that it gets in the lungs, and where did it get the carbon dioxide and other impurities that it brings to the lungs? Let us follow the course of the blood and see.

From the pulmonary veins the blood goes to the left heart and is pumped to the tissues in all organs. And it is here, among the cells of all the tissues, that the real oxidation takes place. It is now definitely taught that most of the food material is oxidized in the lymph around the cells, giving warmth or other energy to the tissues; and that the cells — like all protoplasm — take up and use some oxygen from the surrounding lymph and give up to it carbon dioxide, just as the ameba took oxygen from the water and gave up carbon dioxide to that liquid.

When we exercise vigorously, every muscle cell needs more oxygen, and we grow warm from increased oxidation;

when we have eaten, the secreting cells need more oxygen for their work; when we study, the brain cells need more oxygen and a greater share of the blood goes to the head. So long as a cell is alive it must have oxygen for its work, and it is to satisfy this demand of the cells that the blood must constantly bring oxygen to all the tissues.

This use of oxygen by all the cells in the body is the *real* breathing, and is called *internal respiration*. It gives rise to what may be called vital energy, the activity by means of which protoplasm carries on its work in all cells of the body. It is only under the influence of living protoplasm that the nutrients can be oxidized at such low temperature as obtains in the body.

**Oxidation the Source of Heat in the Body.** — The muscles constitute nearly half of the weight of the body. We know, too, that they are more active than most of the tissues. We would now naturally infer, as indeed is the fact, that they are the chief source of the heat produced in our bodies.

Next to the muscles in importance, as a heat producer, is the liver, which is the largest gland in the body, and, as we shall soon see, one of the most active. The blood, as it leaves the liver by the hepatic vein, is warmer than it is anywhere else in the body.

**The Amount of Carbon Dioxide Given Off.** — When the breath is held for some time, the carbon dioxide in the expired air may reach 7 or 8 per cent. During violent exercise the amount of carbon dioxide given off may be from two to two and a half times as much as when we are at rest. The amount of carbon dioxide given off is increased in cold weather and by taking food, and decreased from one-fifth to one-fourth during sleep. While oxygen is

carried chiefly in the red corpuscles, the carbon dioxide is carried in both plasma and corpuscles.

**Hygiene of Breathing.** — Those persons who take constant exercise in the open air are likely not to suffer much from deficient respiration. But persons following sedentary occupations, such as that of the student, not calling for deep breathing (and often the air taken in is of poor quality), need to pay especial attention to the matter.

**Deep Breathing.**— It is a grateful relief to the whole system to stand, stretch, inhale deeply and slowly several times, and to repeat this every hour or so. Every one engaged in office work or studying should form this habit, especially if he does not give an hour daily to exercise in a gymnasium, or otherwise.

**Breathing through the Mouth.** — We should breathe through the nose, and not through the mouth. The nasal passages are fitted for the introduction of the air (1) by being narrow, but of large area; (2) by having their lining membranes richly supplied with blood; (3) by the abundant secretion of mucus by this membrane. The air, coming through this narrow channel, is warmed, and a large part of any dust it may contain is caught by the sticky mucus that covers all the walls of this passageway. If we breathe through the mouth (especially out of doors in cold weather), the air may not be sufficiently warmed before entering the lungs, and much more dust may be carried into the lungs. Then, too, the air has a drying effect on the throat, whereas the mucus of the nasal passages will moisten the air as it enters. The cilia, which extend from most of the cells lining the respiratory passages, are constantly causing the mucus to flow slowly toward the external opening, so a good share of the dust is gotten rid of.

A further advantage of breathing through the nose is that we then detect odors, and can thus judge of the quality of the air.

**Breathing and Circulation.** — It has been noted that breathing directly aids the circulation of the blood. This is due to the way in which air pressure is made to affect the large veins. Breathing also may very considerably aid the flow of lymph. Every deep inspiration brings pressure to bear on the main lymph duct as the diaphragm descends. Every forced expiration has the same effect. We must keep in mind that the tissues are fed directly by the lymph that surrounds them; that while the lymph is continually fed by the blood, there is not a great pressure given in this way. The lymph stream is largely dependent on the pressure of the surrounding organs. When one takes a good deal of muscular exercise, the lymph is renewed with rapidity enough to supply the tissues with food and to carry away their wastes. But in those who sit quiet a large share of the day, taking no more exercise than is necessary to take them to and from their places of business, the lymph becomes too nearly stagnant, the tissues are not well nourished, and the whole body suffers.

A stooping position at the desk or in manual labor cramps the lungs and prevents their free ventilation. Whenever any part of the lung tissue is not exercised and filled with air at every breath, the cells become inelastic and are much more liable to disease. For this reason clothing should never be worn so tight as to restrict the lungs. If very close about the chest, it hinders the movement of the ribs; if tight around the waist, it prevents the free movement of the diaphragm. And we are also to remember that since breathing is a demand of every tissue and every cell in the

body, the failure of these to receive oxygen means injury to their nutrition — an injury which may be fatal.

**Diseases of the Respiratory Organs.** — All common colds are the results of the chilling of the skin for a considerable time. The low temperature, by nervous reflex, contracts the arterioles of the skin, and blood is forced into the less resistant mucous membrane of the nose or throat, congesting these areas. Waste matter accumulates and, poisoning the tissues, causes inflammation and pain.

The obvious remedy is: (1) Prevention. If the body is in vigorous condition, ordinary chilling will be succeeded in a short time by warmth. When this does not take place, the blood must be restored to the skin by additional clothing, exercise, or hot drinks. (2) Failing in this, the above remedies are to be applied in such exaggerated form as to cause profuse perspiration for from twelve to twenty-five minutes. This excess of blood in the skin reverses the process of cold taking. It withdraws blood from the congested organ to the skin, relieving pain and swelling. With the blood goes some of the poisonous matter that kept up the congestion by irritation, and now healing may take place.

What is a counter-irritant? How may it relieve a sore throat?

*Bronchitis*, *laryngitis*, and *pharyngitis* are names of the inflammatory diseases of the bronchial tube, the larynx, and the pharynx.

*Pneumonia* is a serious inflammatory germ disease of the air sacs themselves. It is one of the most serious and most frequently fatal of all lung diseases. Pain, fever, headache, and backache are warning symptoms. A physician should at once be called.

*Consumption* is a familiar but very dangerous disease. It is the most prevalent lung disease and is commonly called the "white plague."[1]

*Alcohol and Consumption.* — At one time it was widely believed that alcohol was a cure for consumption. This is now known to be so far from the real facts of the case that it is well established that certain forms of consumption are directly attributable to the use of alcoholic drinks. Under the former mistaken view many consumptives used alcoholic liquors to their own injury. But time and experience have taught that alcohol aggravates the trouble.

In *diphtheria*, the specific germs causing the disease lodge in the mucous membrane of the throat, killing it by their activity, and under the false membrane thus formed their poisons (toxins) are absorbed by the blood. These toxins may poison various organs and may even cause death. The modern treatment consists in the injection of an antitoxin prepared in the blood of horses. If taken in the early stages of the disease, it is a positive cure. By means of its use, the death-rate from diphtheria cases in hospitals has been reduced to 2 per cent. Whenever fever continues in connection with a sore throat, a physician should examine the throat and take the temperature of the patient.

*Whooping cough* is a slightly contagious disease, mostly among children, but sometimes taken by their elders.

[1] So called and so dangerous because of its insidious nature. It is caused by a specific consumption germ, a bacillus. As this germ causes nodules or tubercles in the lungs, medical men call it *Bacillus tuberculosis*. The disease is not inherited, as was formerly supposed, but weak lungs *are* inherited. These, and lungs weakened by colds, a catarrhal or an anæmic condition, are fertile ground for the tubercle germs. The germs are spread by the coughing and the sputum of those having the disease.

*Adenoid growths*, chiefly in the nasal passages of children, are not diseases, but they so seriously interfere with proper breathing and mental development that they are mentioned. They can easily be removed by a surgeon. A child afflicted with them looks listless and dull and breathes through its mouth.

Fig. 59. — Adenoids growing between the nose and the throat They swell and obstruct breathing

*Mountain sickness* is said to be due to lack of a sufficient percentage of oxygen in the air, and hence the red corpuscles cannot get enough oxygen for the tissues and there is a sense of suffocation. The same is true in balloon ascensions.

*Caisson disease*, on the other hand, has been attributed to too great air pressure. A caisson is a water-tight chamber of wood or iron in which the work of laying piers or building tunnels is carried on under water. The water is kept out of the chamber by excessive air pressure. Workmen returning from caissons come out through a series of chambers, each under less pressure than the one preceding it, until the normal pressure (one atmosphere) is reached. This is called decompression. If the men remain long enough in each chamber to allow proper decompression, the blood gases do not clog the capillaries and no evil results follow. Otherwise, the tiny air sacs of the lungs become permanently distended and lose their elasticity. In this case, the disease is fatal.

**Pleurisy.** — The covering of the lungs is named the *pleura*. It is a thin, smooth, tough membrane surrounding each lung and also lining the chest cavity. It is thus a sort of double closed sac. A small amount of liquid is secreted

by the pleura and this enables its surfaces to slide over each other when the lungs move in inspiration or expiration. Sometimes, in the case of severe colds, the pleura becomes inflamed, the secretion is not produced, and severe pain results from the inflamed surfaces rubbing upon each other. This inflammation of the pleura is called *pleurisy*. It is seldom fatal.

### QUESTIONS FOR REVIEW

1. What creatures breathe? Make this a general statement.
2. In what different ways do animals breathe?
3. What are the two kinds of respiration? What is the object of each?
4. How does ordinary respiration take place?
5. What are the more important parts of the lungs?
6. By what device do the blood and the air come near each other in the lungs?
7. What are the accessory breathing organs?
8. Name the air tubes. How are they kept open?
9. How does air pressure fill the lungs? (This answer should include work of the diaphragm and rib muscles.)
10. What is meant by residual air, tidal air, and vital capacity?
11. Why is respiration easy? (Give three reasons.)
12. How does respiration compare with heartbeat?
13. What are some modifications of respiration?
14. What is the composition of normal air? of expired air?
15. Why do we use only a portion of the oxygen of the air?
16. What happens when we breathe pure oxygen?
17. Where does *real* respiration take place?
18. How is oxygen carried to the tissues?
19. What is the benefit of oxidation in the tissues?
20. How is carbon dioxide carried to the lungs?
21. What kind of breathing is best? Why?
22. What is the relation between breathing and circulation?
23. In what ways may breathing be harmfully restricted?
24. How is a cold contracted? What are the scientific remedies?

**EXERCISES**

*Illustrating Respiration.* — *A. To learn the number of breaths per minute:* While one student, or the teacher, gives the signals from a watch, "Ready, count," and exactly at the end of a minute, "Ready, stop," the other students are to count the breaths — out-and-in being one breath. After taking the average of three counts, the first count being rejected because of the newness of the exercise, each may record his rate of breathing. In like manner, each student may try to obtain the rate of breathing of another member of the class.

*B. To show the action of the diaphragm and lungs:* Material, bell jar with stopper, sheet of rubber (such as is used by dentists) large enough to cover the mouth of the jar, toy rubber balloon, cork (rubber preferred), glass tube, strong rubber band (such as boys use for sling shots), marble.

Preparation. — Lay the marble on the center of the sheet of rubber, double the rubber over it, stretching the rubber strongly over the marble, and tie the marble firmly in its place. Stretch the sheet of rubber over the mouth of the jar with the projection made by the marble on the outside, and fasten with rubber band. Bore a hole in the cork, and fix the glass tube snugly in it, so that the lower end of the glass tube will extend about half-way down the jar. Tie the balloon on the lower end of the glass tube.

If a bell jar be not at hand, a lamp chimney or a quart bottle may be used, after cutting off the bottom, as follows: File a deep notch across near the bottom of the bottle; heat an iron rod, and apply the end of it to one end of the notch, and slowly draw the rod around to the other end of the notch (the rod may need to be reheated). After cracking off the bottom of the bottle, file the edges so they will not cut the rubber.

Again inflate the balloon, and while it is inflated tightly cork the jar. If all the parts fit well, the balloon should now remain inflated. This may at first seem strange, as the mouth is taken away from the tube, and the tube left entirely open to the air. But it will be seen that to just the extent that the balloon contracts, so much more space is left in the jar outside the balloon. This means diminished pressure, and the pressure of the outer air presses the diaphragm up, and keeps the balloon partly distended, maintaining equilibrium.

Pull the diaphragm down, using the marble as a handle. This shows the expansion of the lung by the pressure of the external air when more space is given by the depression of the diaphragm. On releasing the diaphragm, it springs upward, and the balloon becomes reduced in size, driving out part of the air that was in it. This shows how expiration is accomplished, so far as the diaphragm is concerned.

Where sheet rubber cannot be had, a basin large enough to contain the bottom of jar or bottle, and filled with water two inches deep will take the place of the membrane. If the bottle is held up with one hand, the basin may be raised and lowered an inch with the other, while the lower edge of the bottle or jar is kept in the water. If there is no stopper or glass tube at hand, a piece of potato and a quill will serve the same purpose.

*C. To learn the capacity of the lungs.* — Use a spirometer.

NOTE. — **A Spirometer.** — Ordinarily the vital capacity is measured by a spirometer; a simple one may be improvised by one of the students if there is a laboratory at hand. It is constructed on the principle of the gas reservoirs in large cities, and has an outer tank of glass or tin to contain about 800 cubic inches, and an inner tank, one-half the depth, to contain about 300 cubic inches. The inner tank is inverted in the outer one, its bottom up, being provided with a tube to which may be attached a rubber tube several feet long with a glass mouthpiece. The center of the inner tank should have a hook on the bottom by which to support the tank by a counterweight over a pulley. (Pictures may be found in catalogues.)

After the inner tank has settled in the water — which fills the outer tank a little over half full — until all the air of the inner tank is displaced, vital capacity is measured by blowing through the tube into the inner tank after taking as full a breath as possible. The height to which the inner tank rises, as previously measured in cubic inches, is the vital capacity. It is a safer method to hold the inner tank at the surface of the water and measure the capacity by drawing air from the inner tank and noting how deep it sinks in the water. This should never be done after another student has blown air from his lungs into the inner tank. The latter must be filled with fresh air.

*D. To learn the nature and amount of Oxygen, Nitrogen, and Carbon Dioxide, in the Air.* — 1. The Nature of Nitrogen. — Into a pint

fruit jar having a good rubber ring pour two heaping teaspoons of pyrogallic acid and two ounces of strong solution of caustic soda. Quickly close the jar air-tight, and shake slowly for five minutes. The chemicals take the oxygen and carbon dioxide out of the air. What gas will be left? Turning the jar over, open the mouth under water in a deep dish. Put the cover on again while the mouth of the jar is still under water, remove the jar, and set in an upright position on a table. Test the nitrogen by thrusting a flaming splinter into the jar when the cover has been removed slowly. What property of nitrogen is shown?

2. The Proportion of Nitrogen and Oxygen in the Air. — By measuring the liquid now in the jar and subtracting the amount poured in (2 oz.) we get approximately the volume of oxygen in a pint of air, the carbon dioxide forming only one twenty-fifth of the atmosphere. What proportion of the atmosphere is oxygen? How can we get the proportion and volume of nitrogen?

3. The Nature of Carbon Dioxide. — Known carbon dioxide is obtained by dissolving broken marble or clam shells in dilute acid (washing soda crystals and vinegar will do) in a fruit jar or pickle bottle. How does a flaming splinter behave when thrust into this gas? Cover the jar and save the gas for Ex. *E*, 3 *a*, below.

4. Now recalling (*a*) the effect of nitrogen gas on a burning splinter, and (*b*) the effect of carbon dioxide gas on a flaming splinter, which gas of the *air mixture* is indicated as the one that keeps up burning and is therefore useful to the body?

5. If a gas generator is at hand, these experiments can be more satisfactorily done. A little oxygen can be generated in a test tube in which has been placed a mixture of chlorate of potash and manganese dioxide. The lower end of the tube is strongly heated in an alcohol flame while holding a burning splinter in the mouth of the tube. The brightness of the flame will show when oxygen is given off; then the splinter is to be blown out, leaving only a spark at the end which is thrust into the tube to see it burst into flame.

*E. To learn the products in Expired Air.* — 1. Breathe into a clean, cold tumbler, or on a cool glass plate. What *substance* is shown to be present in expired air? Why can we see our breath on a very cold winter morning?

2. Hold a thermometer away from the body and read the tempera-

ture. It indicates the temperature of the air you are breathing in. Breathe for a few minutes on the bulb of the thermometer as if warming the hands. How has the temperature of the air changed in the body? Reading the temperature after the bulb has been held under the tongue for two minutes will suggest a reason for the correct answer.

3. (*a*) Suggest a reason for looking for carbon dioxide in expired air. A test for carbon dioxide is limewater. This is made by pouring a quart of water over two tablespoonfuls of quicklime (air-slaked lime will do, but no kind of cement can be used), shaking well, and letting it stand until clear. A little limewater is now poured into a tumbler, and then a little known carbon dioxide may be poured from the jar in Ex. *D*, 3, by holding the cover of the jar so as to direct the gas into the tumbler. Quickly cover the tumbler with the hand and shake the limewater until it touches the hand. The milky appearance — a precipitate that the carbon dioxide causes in the limewater — is the test, as no other gas gives this result. (*b*) Again pour some clear limewater into a small tumbler, breathe on the limewater, cover with the hand, and shake. The result will be more certain if one blows the breath through the limewater with a tube, quill, or straw. What gas is given out in the breath?

*F*. Whether oxygen and nitrogen are given out in expired air may be learned by modifying Ex. *D*, 1, as follows: The pint screw-cap jar is filled with water and inverted in a deep dish of water. With a curved tube of any kind it is breathed full of air, replacing the water. The powder pyrogallic acid and a piece of caustic potash or soda are placed in the cover of the can. The cover is then slipped under the mouth of the jar which has been brought near the surface of the water. After the cover is screwed on air-tight we proceed as in *D*, 1.

# CHAPTER VIII

## THE EXCRETORY SYSTEM

**Introductory.** — It is often more important to rid the body of wastes — excretions — than to supply food for a given time. The simplest animals, as well as all others, have to get rid of nitrogenous and other waste substances.

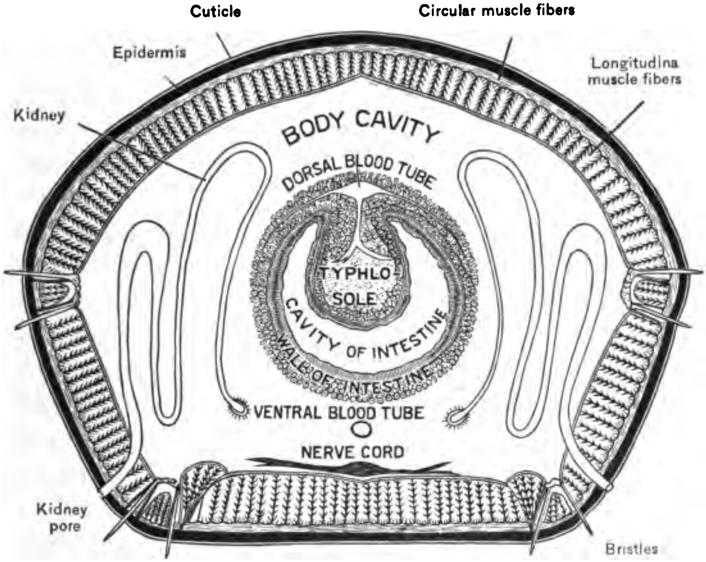



Fig. 60.—One ring or segment of an earthworm, showing kidney tubes (*From Colton's Zoölogy.*) See page 154.

As stated in the first chapter, the ameba gives out carbon dioxide, and, from a pulsating vacuole, the liquid waste is ejected. In earthworms there is a pair of coiled kidney tubes in each ring or segment of the body. Fishes and

frogs are among the lowest animals that have a bladder, but birds and reptiles have no bladder or reservoir, and so have no watery urine. The white, sticky part of bird droppings is the urine in their case.

**The Organs that are Excretory.** — Strictly speaking, such a system should include all the organs that take part in getting rid of the waste products of the body. The lungs, besides getting oxygen to the blood, give out the wastes, carbon dioxide and water, and to this extent they are excretory organs. The rectal portion of the large intestine holds and periodically gives off the *feces*, the waste products of digestion and the liver. The liver itself is an important excretory gland. The skin is a more or less important organ[1] of excretion, as water and some salts are given out through its glands. These products (perspiration) are, however, for another purpose, as will be seen elsewhere. (See Chap. IX, The Skin.)

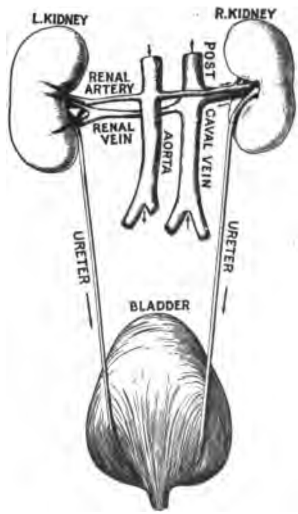


Fig. 61.—The kidneys and the bladder. Dorsal view.

**Excretion.** — Usually the skin and the kidneys are treated under the above heading, though the kidneys are really the only purely excretory organs of the body — the only organs that have no other function.

[1] If you are in doubt about calling the whole skin an organ, remember (Chap. I) the definition of an organ, and that the epidermis of the skin is composed of cells doing one kind of work.

**The Work of the Kidneys.** — One important part of the work of the lungs, as we have seen, is to throw out carbon dioxide. The skin also throws off certain wastes. The kidneys have the special task of excreting a waste product of the body called urea. Urea is the protein-containing waste.

**The Parts of the Kidneys.** — The kidneys are attached to the dorsal wall of the abdominal cavity. (See Fig. 37 *A*; 47.) Their upper ends are just under the lowest ribs felt in the back. Locate them with your thumbs while your hands clasp your sides as if pulling down the waistline. The kidneys are as long as the hand is broad, a little thicker than the hand, and somewhat bean-shaped. In fact, the variety of bean called the "kidney bean" is so called because of its resemblance in shape to that of the kidney. The depression in the kidney corresponding to the stem scar on a bean is called the *hilum*. From the *hilum* issues a white tube, the ureter, which conveys the urine to the bladder. (See Fig. 61.)

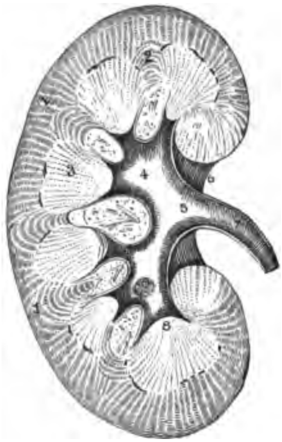


Fig. 62. — Half kidney, showing the inside

1. Cortex, where the tubules begin; 2. Outer; 3. Inner urinary cores; 4. Pelvis of kidney; 5. Ureter; 6. Hilum. (*After Gegenbauer.*)

**The Blood Supply of the Kidneys.** — Entering the kidney alongside the ureter is the renal artery, a branch of the aorta, and from near the same point the renal vein returns the blood from the kidneys, and pours it into the post-caval vein. Through the kidneys is pouring a continuous stream of blood, varying in amount at different times and in different conditions. The kidney receives a very large amount of

blood for its size, as compared with other organs. The flow to it is made easy by the fact that the renal arteries are relatively wide and short, and take the blood directly from the main current of the aorta. The blood leaving the kidney, especially when in full activity, is still bright red; it is probably the purest blood in the body.

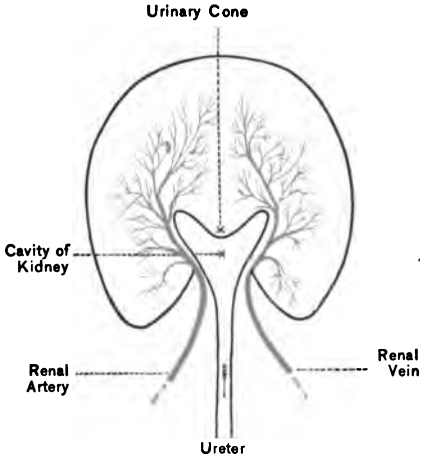


Fig. 63. — Cross section of kidney — through No. 5 in Fig. 62

**How the Kidneys Work.** — The student is now supposed to understand that the secreting cells of all glands are microscopic in size. When a very thin piece of a prepared kidney no larger than the letter *k* (of this type) is examined under the microscope, it is seen to contain a number of minute coiled tubes.[1] The secreting portion of these tubules is lined with secreting cells and covered with capillaries. These capillaries pass the urea from the blood through the cells into the hollow of the tubules. The ends of the tubules [2] are enlarged into capsules and each capsule also contains a coil of capillaries. As the blood flows through the tuft of capillaries in the capsule at the end of the tube, a large amount of water together with salt and some other substances pass through the thin partition into the cavity of the capsule, and thence down the tube. The

[1] The uriniferous tubules.

[2] Toward the outside or cortex of the kidney.

walls of the tube are thicker than, and its cells are different from, those of the capsule. These cells take the urea and some other substances from the blood, and pass them into the tube to join the more watery material from the capsule.

The combination of urea and water, the urine, is then carried by thousands of these tubules, joining one another from all parts of each kidney to the hollow or hilum of each, and thence into the funnel of the ureter. (See Fig. 62.)

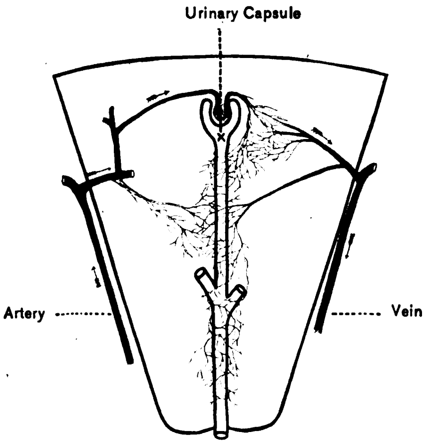



Fig. 64.—One uriniferous tubule with capsule, highly magnified. Why are both artery and vein red? What is removed in the kidneys?

**Urine.** — From the kidney, through the ureter, urine is continually passing to the bladder. Urine is mostly water containing urea, salt, and various other substances in small amounts. Urea is a waste matter brought in the blood. If the kidneys are stopped in their action, urea accumulates in the blood, and death soon results; to just the degree that the kidneys fail in performing their duty, just so far must the body suffer.

**Relation between the Work of the Kidneys and that of the Skin.** — There is a very immediate relation between the work of the kidneys and that of the skin. In warm weather, and when exercising actively, we perspire freely, and the amount of urine is reduced; when we exercise less, and especially in cold weather, we perspire less, and the urine is more abundant. Cold drives the blood from the surface.

Consequently more blood goes to the kidneys (as well as to the other internal organs), and they throw off much more water, though probably little if any more urea. The average daily amount of urine is about three pints. The quantity is increased by high blood pressure, copious drinking, by cold air, nitrogenous food, certain drugs, etc. It is diminished by a lowered blood pressure, profuse sweating, diarrhea, non-nitrogenous food, and some diseases of the kidneys, and by certain drugs. These facts show that blood pressure rather than nerve impulse regulates the secretion of urine.

## Hygiene

*Ridding the body of wastes* is so necessary to health that as careful attention should be paid to excretion as to any other of the living processes. Water is the dissolver and carrier of all the body material — for waste as well as for growth and nutrition. Of course, drinking freely has a beneficial effect upon the kidneys, since it increases the blood flow through them, except when we perspire abundantly. Some physicians say that nobody can drink too much pure water. Three pints per day is a moderate amount for the average adult; it is said the Japanese drink nearly three quarts. It is advised to take most of this between meals, though the drinking of water moderately and slowly at table does not injure the digestion.

The liver and kidneys are so closely related that whatever harms one of them seriously affects the other. Over-indulgence in sweets and in protein food, — especially meat, — constipation, overeating, and lack of exercise injure both organs. They are also liable to injury by exposure or over-exertion during the weakness of convales-

cence, especially when the illness has been a germ disease, in which toxins, as well as the ordinary body wastes, have required elimination.

*Diuretics* are substances that increase the secretion of urine, such as salt, onions, certain drugs, etc.

*Alcoholic drinks* act like diuretics on the kidneys. German physicians and others attribute Bright's disease to excessive use of alcoholic beverages. They weaken the kidneys by overworking them and then they are easily subject to disease. See also Nutrition and Oxidation.

Every one should know that "kidney trouble" is rarely accompanied by pain, at least in its early stages. The pain, or tired feeling, that many persons have in the "small of the back," is often due to strained muscles, the kidneys being higher up, as is seen by consulting page 105 and Fig. 47. Remembering these facts, no one should be defrauded by advertised kidney remedies. *Reputable physicians never advertise.*

**Diseases of the Kidneys.** — It has already been pointed out (page 113) that in the case of excess of sugar in the blood it may be excreted by the kidneys. There is a serious disease of this kind called *diabetes*.[1] It is mentioned here because it has been by some considered a disease of the kidneys. But the kidneys act more like a scavenger or garbage collector. If people throw sugar into their refuse holder, the collector takes it the same as waste.

*Bright's disease* is indicated to the physician by the presence of albumen in the urine. This albumen has, of course, been secreted from the blood flowing through the

[1] It is not primarily a diseased condition of the kidneys, but is due to faulty nutrition, often caused by a diseased pancreas. Diabetes may even result from an injury to the brain.

kidneys, and the action may go so far as fatally to weaken the patient. Though serious inflammation is taking place in the kidneys, it is not indicated by pain.

*Urinary calculi*, or "kidney stones," little masses of mineral deposit in the hilum of the kidney, cause severe pain only when they block the ureter. Certain acids taken in drinking water from time to time prevent the formation of urinary calculi or dissolve them without pain.

This again emphasizes the need of drinking much water as it helps to keep mineral salts in solution and also aids in the removing of urea.

### QUESTIONS FOR REVIEW

1. What organs take part in removing wastes from the body?
2. What are the parts of the excretory system proper?
3. Where are the kidneys located?
4. How do the glandular tubes of the kidneys work? What is their structure?
5. What disease commonly attributed to the kidneys is due to malnutrition?
6. Why should we drink much water? How much per day?
7. What are some diuretics, in name and effect?
8. What is good advice on kidney diseases and patent medicines?
9. What is a common cause of pain in the small of the back?

# CHAPTER IX

## THE SKIN

Although the skin is usually discussed under the excretory system, excretion is its minor function.[1] In lower animals, from worms up, the skin is primarily for protection and feeling.[2] In most of these it has glands for secreting substances which counteract the effect of air or water in which they live. The glands in our own skin are of similar origin and are of two kinds, sweat glands and oil glands.

**How the Sweat Glands Work.** — The sweat glands are minute tubes whose inner ends are closed, and whose outer ends open upon the surface of the skin. The tube going inward pursues a corkscrew-like course through the epidermis, then becomes straighter, and, having passed through the dermis, is coiled up in a ball in the connective tissue

[1] "The main fact to be considered in the secretion of sweat is the formation of water." (Howell). Another writer says, "If the skin were varnished, the same excretion would easily be eliminated by the kidneys." It would, however, be well to state that such stoppage of the skin has often caused death. There is a story of a monkey on shipboard, who, seeing the sailors use paint and brush, proceeded — when unobserved — to paint his mate, and with fatal results. There are cases on record where covering the human body with substances that prevented perspiration from coming to the surface proved fatal. But this result is not because of interference with any excretory function of the skin, but because the action destroyed its heat-regulating function. In man, this function is as important as is the protective one.

[2] The sensory or feeling function of the skin will be discussed under Touch. In earthworms and frogs the skin is also an organ of respiration.

lying just underneath the inner skin. The cells forming the walls of the coiled part differ from those of the duct, or straighter part of the tube. As the blood flows around the coil, it gives off lymph, and from the lymph the cells of the gland take certain waste matters, which are passed out to the surface of the skin. There is also some muscular tissue around the walls of the gland.

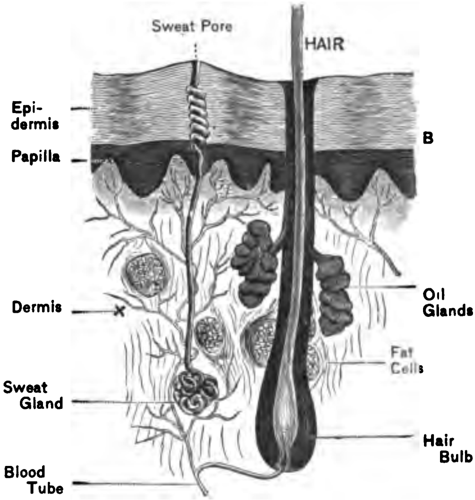



Fig. 65. — Vertical section of the skin

**Glands and the Blood Supply.** — The sweat glands, like all glands, are largely dependent on the amount of blood supply. In exercising, the skin is usually redder from the greater blood supply, and at the same time the glands are more active; for, during exercise and immediately after it, there is more waste matter to be thrown out. But the activity of the gland is not a mere filtering process, due to the greater blood pressure. There may be a cold sweat; *i.e.* when the skin is pale. Here is evidence that the activity of the glands is, primarily, due to the nerve impulses from some nerve center to the gland cells.

**The Oil Glands.** — The oil glands of the skin are distributed over all the surface except the palms of the hands

and soles of the feet. The oily matter is usually poured out around the hairs as they emerge from the skin. It serves to oil the hair and the skin, and keep them from becoming too dry.

**Distribution of Sweat Glands.** — The sweat glands are thickly distributed over the whole surface of the body, but are especially numerous and large on the palms of the hands and the soles of the feet. In the armpits the glands are very large. There are about two million sweat glands in the skin.

**Sweat or Perspiration.** — Sweat is mostly water; about 1 per cent is solid matter, including salt and certain materials which, like the organic waste matter from the lungs, easily putrefy, and some oily matter from the oil glands of the skin.

**Kinds of Perspiration.** — Ordinarily the sweat is evaporated as fast as it is poured out; in distinction from this insensible perspiration, there is the so-called sensible perspiration — when it accumulates enough to be perceptible. These are not two distinct kinds of sweat, but it is convenient to distinguish between the perceptible and the imperceptible. Sweat varies greatly in its wateriness, and hence in the *relative* amount of solid matter contained.

**The Amount of Perspiration.** — There is about one quart in twenty-four hours. It varies with: —

1. Temperature, dryness, and rate of renewal of air.

2. Condition of the blood; *e.g.* if watery from drinking much water.

3. Muscular exercise.

4. Certain drugs — some exciting perspiration, others diminishing it.

5. The nerves exercise great influence on the activity of the cells of the glands.

**The Structure of the Skin.** — The skin has two layers, the inner, or dermis, and the outer, or epidermis. A bruise often loosens or breaks off a piece of the epidermis, but seldom removes the dermis. The epidermis is thick over the palms of the hands and soles of the feet; elsewhere it

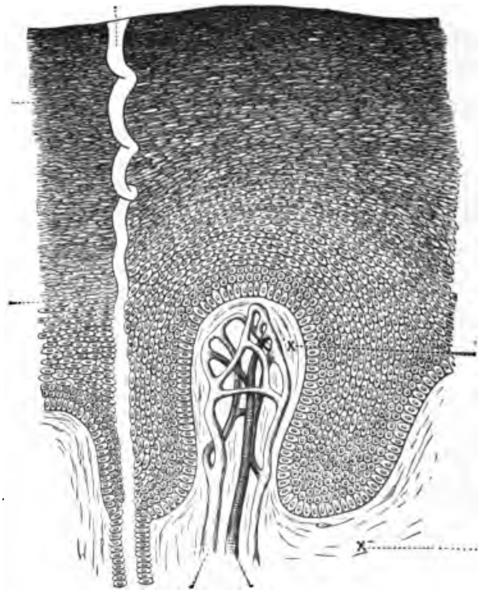



Fig. 66.—Section of epidermis, showing papilla. (Highly magnified.)

is thin. Not often seeing the whole thickness of the skin, we do not easily obtain an idea of its real thickness. The skin constitutes about one-fifteenth of the body's weight. (See Fig. 65.)

**The Epidermis.** — The epidermis consists of many layers of cells packed closely together. The deepest cells may be compared to grapes with their cell walls plumply

filled out by the liquids of the cell. Suppose, for the inner layer, grapes set on end, and so closely packed together as to press each other into elongated prisms; then layers less closely pressed, more nearly spherical; then layers of cells with less liquid in them, and somewhat shrunken, like raisins; then still drier cells, flattened parallel with the surface of the skin; and last, in the outer part, layers of cell walls, dry and empty, pressed flat like empty grape skins. The flat cell walls come off in flakes (those from the scalp are called dandruff) from all the surface of the skin, and new cells are continually formed in the deeper layers.

**The Color of the Skin.** — The pigment, which gives color to the skin, lies in the deeper layers of the epidermis. In albinos this is wanting; in persons with a fair skin it is small in amount, in dark skins more abundant. Where the pigment is irregularly scattered it causes freckles.

**A Blister.** — A blister is caused by separating the two layers of the epidermis, the inner, softer, darker layer from the outer as shown at *B* in Fig. 65. Serum, or blood, fills the space between the separated layers.

**Hairs and Nails.** — Hairs and nails are outgrowths of the epidermis. Their deeper parts are embedded in the dermis, through which, from the blood, they derive their nourishment. Like the epidermis, they are dead in the outermost part, and are supplied by growth from beneath.

**Examination of the Skin with a Lens.** — Place a linen tester, or a good pocket lens, on the palm of the hand and note the openings of the ducts of the sweat glands, or sweat pores. Count the pores within the square shown. Measure this square, and then estimate the number of sweat glands to a square inch of the palm.

**The Dermis.** — The dermis consists chiefly of tough interlacing fibers. Hence the strength and durability of

leather, which is the dermis of animals preserved and prepared. The dermis is richly supplied with blood capillaries and lymph capillaries, but the epidermis has neither.

The outer surface of the dermis has numerous conical elevations, called *papillæ*. Over most of the skin there is no evidence of these papillæ, as the epidermis covers them. But on the palm and sole the papillæ are in rows, and these rows are indicated by the fine ridges.

**The Functions of the Skin.** —

| | | | |
|---|---|---|---|
| In man | 1. Heat-regulating . . . . . | 0 | In lower animals. |
| | 2. Sensory — organ of touch . . | 2 | |
| | 3. Protective . . . . . . . . | 1 | |
| | 4. Excretory . . . . . . . . | 3 | |

The heat regulation by the skin is the most important for our present consideration.

**Regulation of the Temperature of the Body by the Skin.** — It is a striking fact that, except in disease, the temperature of the body varies only a little from 98.5° F. in summer and winter, during exercise and rest. The rate of heat production varies greatly. The rate of giving off heat must, therefore, vary accordingly.

In considering the regulation of the body's temperature, we must bear in mind that the body is surrounded by air almost always considerably cooler than itself. The body is, therefore, almost always giving off heat. Our clothes do not warm us: we warm them, and they keep us from warming the air too fast; *i.e.* keep us from losing too much heat. Indoor heat in winter in the cooler parts of the United States is kept at about 70° F. by artificial heat. This air does not warm us. We, being about 30° F. warmer, are warming it.

**Ways of Giving off Heat.** — The skin gives off heat by: —

1. *Radiation:* Heat is given off in every direction.

2. *Conduction:* Whatever we touch that is cooler than our bodies is warmed. We warm chairs, clothing, etc.

3. *Convection:* The air in contact with the skin is warmed and rises. Our bodily heat is thus carried off by convection.

4. *Evaporation:* The evaporation of the sweat is a much more important factor in heat regulation. Any liquid, in evaporating, absorbs heat. The cooling effect of alcohol or ether on the skin is due to the fact that heat is taken from the body in converting the liquid into a gas, evaporation.

NOTE. — Let the teacher, with a medicine dropper, place a drop of alcohol, ether, or cologne on the back of the hand of each pupil. Notice two facts: (1) It produces a cooling effect. (2) The liquid soon disappears, evaporates. We sprinkle the floor in hot weather, and, by the absorption of heat in evaporating the water, cool the air of the room.

**Heat and Exercise.** — When we exercise, we produce more heat: we sweat more; more heat is taken from the body to evaporate this sweat. If we are not exercising, and are in cooler air, we sweat less, and less heat is given off. So the temperature of the body is kept uniform.

This should also be observed: When we exercise, more blood is in the skin, and more heat is given off in the other ways mentioned; when we exercise less, the skin, especially in a cool air, becomes paler; *i.e.* has less blood in it, and heat is economized.

**Distribution of Heat in the Body.** — If more heat is produced in one part of the body than in the others, the circulation of the blood tends to equalize the temperatures

of the different parts. So, too, if one part is cooled, — that is, is losing heat faster than the others, — the blood brings heat from other organs to that part.

For instance, if one holds his hands in the snow, or puts a piece of ice on his wrist, the whole blood stream is affected. So if the hands and the feet are exposed to the cold, it may do little good to have the rest of the body covered. A pair of wristers and a pair of leggings may often add more to one's comfort than a heavy overcoat.

**Regulation of Bodily Temperature by Food and Clothing.** — When subject to the influence of cold we eat more; we choose more heat-producing foods, as fatty foodstuffs; we take more vigorous exercise; we put on more clothing, and especially of the non-conducting kinds — woolens. In warmer weather we eat less fatty matter, wear less clothing, and are less disposed to exercise actively; we fan ourselves to help get rid of heat; we take ices and cold drinks. For most persons it seems better to wear woolen in winter time, as we are then subject to sudden changes in the temperature of the air, and with such covering one is less likely to take cold.

As stated at the outset, temperature regulation is one of the most important functions of the skin. Mammals, including man, are called warm-blooded because of their high internal temperature, 98.6° F. This high temperature is not largely due to our covering, as is sometimes stated, but to rapid oxidation, the greater internal activity taking place in mammals. In order to keep this temperature well regulated, the skin must be kept clean and in constant practice, so to speak.

**The Effect of Wet Clothing.** — In getting the clothing wet, the greater loss of heat is not from the coolness of the water, but the loss

of heat in evaporating the water from the clothing. Of course it is desirable to put on dry clothing as soon as possible; but a person in good health is not likely to take cold, except in very cold weather, if he continues active exercise till he can change the wet garments for dry ones. Children do not often take cold from wading in water, so long as they are barefooted; but if the shoes and stockings are wet, they are likely to take cold.

**Alcohol and Heat.** — The usual effect of a moderate dose of alcohol is to make the person feel warmer. There is more blood in the skin, where the nerve endings perceive the effect. More heat is brought to the surface and more is given off from the body. A thermometer has no "feelings" by which it can be deluded. The thermometer says that the body is losing heat. It is as though one were to open a window, and as the warm air rushes out by him, were to say, "It is getting warmer," not recognizing the loss of heat. There is some heat produced in the body by the oxidation of the alcohol, but this is overbalanced by the loss, as shown by a thermometer. The fact has been clearly shown by experiment, that alcohol deadens the senses, and neither heat nor cold is so readily perceived as before. And this deadening of the senses also makes one fail to notice fatigue; hence the delusion that the fatigue is gone.

**Exercise of Arterial Muscles.** — We have learned that the blood supply to any organ is regulated by the action of the plain muscle fibers in the walls of the small arteries. Now, when we are subject to changes in temperature, these muscles get exercise. One writer has well called the cold bath the *gymnastics of the plain muscle fibers*, and we can understand how the system can be trained to adjust itself to cold, and be enabled to avoid "taking cold" so frequently.

**"Taking Cold."** — So long as one is actively exercising, he is not likely to take cold. But if one rests in a cool place, especially when he is warm, he is, as we all too well know, likely to take cold. As we saw when we were studying the circulation of the blood, the application of cold to the skin causes the arteries (through reflex action) to become smaller. Thus, when resting in a cool place, the skin becomes pale and cold.

During a "cold" there is fever. The regulation of the heat by the skin is interfered with. At the same time it is often noticeable that the urine is more abundant than usual. As a cold may lead to fatal lung disease, so it may be the beginning of some disease of the kidneys that may, in the end, bring fatal results.

**Bathing.** — One purpose of bathing is to cleanse the skin. For this purpose warm water is best, and it is desirable to use soap on those parts which are especially exposed to contamination, such as the hands, the feet, the armpits, and the groins.

**Bath Mits.** — Instead of the sponge and the ordinary form of towel, it may be found more convenient to use bath mits made of Turkish toweling. These are easily made, and are somewhat more convenient, as thus friction may be more readily applied than with a towel, which is apt to slip in the hand. The two hands may be used at the same time, and the whole time of the bath need not exceed two or three minutes. At the beginning of a bath, cold water should be applied to the head and face.

**Time for Bathing.** — For students, or others who do not take a great deal of vigorous exercise, this means of keeping the skin active is especially valuable. The use of warm water for cleansing seems best adapted (for busy

people) to the time of going to bed. But the best time for the cool bath is on getting up in the morning.

**Warm Baths *vs.* Cold Baths.** — Prolonged warm baths are debilitating, and probably increase a tendency to take cold, whereas cold bathing is one of the very best means of fortifying against cold, and especially against the tendency to take cold on slight exposure. For most persons a cool sponge bath, on rising, will act as a most excellent tonic; but if it seems to produce neuralgia, it should be used with caution.

**Cold Baths.** — Another important function of bathing is to act as a systemic tonic. For this purpose cold bathing is better, but this should not be too long continued, and must be followed by brisk friction to give the skin a ruddy glow. For this kind of bath a tub is not necessary, and hardly desirable. The water may be quickly applied by means of a sponge, and the body thoroughly rubbed with a coarse towel. The whole process should be completed very quickly, especially if the room is not warm.

There are undoubtedly many persons who do not profit by cold bathing, but probably many of these would soon adapt themselves to it by beginning with tepid water and gradually using cooler. And the great secret of the benefit that may be expected from the operation, as most people are situated, is to be very brisk, the whole process occupying only a few minutes. Many are opposed to cold sponge bathing, and condemn it without reserve, when, probably, they have never really given it a fair trial.

Let it be repeated, with emphasis, that for students it is one of the *very best means of preserving health.*

**Affections of the Skin.** — Corns and warts are thick, horny masses of dead epidermis cells caused by irritation or

pressure. Ordinary eruptions of the skin can be remedied by carefulness in the matter of diet and fresh air. These ailments of childhood disappear at about twenty years of age. While scrofula and eczema are called skin diseases, they are really due to a disordered condition of the blood. Scurvy, already noted under Foods and Their Uses, attacks mainly fishermen, sailors, and soldiers. Vegetable diet will prevent and cure it.

Boils and carbuncles are usually due to an impaired nutrition of tissues. These, then, become a suitable medium for the growth of germs that get into the skin through a slight injury, or even through the inactive glands. "Colds" have this effect on the skin of some persons, being followed by a "crop of boils." In other cases bruises and contusions, or local pressure, long continued, impair the tissues. It is not true, as some people believe, that boils are beneficial in removing effete matter from the system or that one must have them periodically. The best treatment for them is cleansing and disinfection, as for wounds, and attention to the diet.

Red local swellings are in the nature of congestion (see Circulation), and the pus in boils is mostly dead white corpuscles, disintegrated cells, and germs. The white corpuscles, or leucocytes, come to the sore spot in great numbers in response to the irritation of harmful substances, and then cannot get enough oxygen to keep alive.

Itch is a "catching" disease, due to a mite burrowing in the skin. The intense itching is first felt between the fingers where they join the hand. Affected parts should frequently be anointed with a salve of vaseline and powdered sulphur, and this again removed after an hour or two.

Several diseases are characterized in some part of their course by skin eruptions. These are scarlet fever, smallpox, chicken pox, and measles. The specific germs that cause each of these diseases usually go into a spore stage, or resting stage, when the disease has run its course and while the eruptions are healing. In this stage the germs are more resistant and may be carried by the scattered scales, or matter from the eruptions, and thus spread the disease. All such material from the body, and all clothing and bedding, should be disinfected, and the patient kept quarantined. (See Incubation Table, also Disinfectants, in the Appendix.)

Vaccination for smallpox is a skin operation and involves the blood, the plasma forming antigens to the smallpox germ. Cowpox toxin is the substance used to inoculate the blood. It is very important that every one be vaccinated whenever there is a smallpox epidemic, unless he has been successfully vaccinated within five years — the period of immunity.

The discovery of vaccination by cowpox virus was made in England in 1775 by Edward Jenner, a young physician.

Fifty years before Lady Montague, wife of the English ambassador to Turkey, had brought home the knowledge of inoculation with smallpox virus as it was practiced in that country.

Urticaria or " hives " is a very troublesome burning and itching rash on portions of the body. Some people are afflicted only when exposed to sea air. In such cases change of locality brings relief.

### QUESTIONS FOR REVIEW

1. What is one of the most important uses of the skin to our bodies?

2. What are its primary uses in lower animals? How could glands protect?

3. What is the perspiration in composition and origin?

4. What evidence that it is regulated by nerve action?

5. Where are the most numerous sweat glands?

6. What things affect the amount of perspiration?

7. What are the functions of the skin?

8. What is the normal temperature of the body under the skin? How kept so?

9. How does the physician tell? What preliminary indication for fever heat does he feel? What degree is danger signal?

10. What are the layers of the skin? What is the structure of each?

11. What organs are present in the under layer?

12. Where does a blister come? What is the cause? Best treatment?

13. Why is it desirable to keep the skin clean? What kind of bath for this purpose?

14. What is the rôle played by the skin in cold taking? What is the rest of the mechanism?

15. How may baths be used to harden one?

16. What is the relation between the work of the kidneys and the skin?

### EXERCISES

*The Functions of the Skin.* — 1. To learn whether we give off moisture only when visibly perspiring: At intervals during the class period one of the fingers is thrust into a cool, dry, test tube or wide-mouth bottle. The best result obtained by any member of the class should be seen by all the others at the close of the exercise. What has the amount of blood in the skin to do with the moisture given off? When does more blood come to the skin? What becomes of the perspiration of the skin?

2. To learn how evaporating moisture affects the heat of the skin: The bulb of a thermometer is dipped in alcohol to remove any

grease; then it is dipped in water about half a degree lower than room temperature. As soon as this temperature is noted the thermometer is held in the air until it is clear whether the temperature is rising or falling. Now swing the thermometer back and forth in the air until all the water has evaporated from the bulb, indicated by the mercury column moving in the opposite direction, and note the temperature at this point. Did the temperature rise or fall? How many degrees? What is the benefit of perspiring? Why do we feel very uncomfortable on warm *damp* days?

3. To learn the effect of wet clothing on the skin: The bulb of a thermometer is covered with cheesecloth and dipped in water about a half degree lower than the room temperature. When this is noted the thermometer is swung about in the air or hung up until the water has evaporated, noting the lowest degree reached. How do the number of degrees of heat lost and the length of time of evaporation in 2 and 3 compare? What danger is there in allowing wet, or even damp, clothing to dry on the body?

4. To illustrate other ways in which the skin gives off heat: (*a*) How it affects colder objects touching it is shown by holding the bulb of a thermometer in the hand until the temperature changes no more. When this temperature is noted it must be compared with room temperature. Why? (*b*) How the skin affects colder objects near, but not touching it, is shown as follows: The left hand is partly closed to form a cup, the thumb and index finger forming the upper edge, the little finger closing the bottom. Within this cup the bulb of a thermometer is held in such a way that it does not touch the skin. When the temperature remains constant it is compared with that of the room. Hold the little finger of the right hand in the cup without touching the skin of the left hand. How does the skin lose heat? The method illustrated in (*a*) is called "conduction," and that shown by (*b*) is called "radiation."

5. With a magnifier (tripod) the sweat pores may be seen on the fine ridges of the finger tips. Immediately after taking the finger out of the bottle in experiment 1, glistening bits of moisture may be seen in the pores.

# CHAPTER X

## THE SKELETAL SYSTEM

**Introduction.** — In the study of food, digestion, circulation, and respiration we considered the action and the structure of organs that carry on the necessary work of living — the so-called vital processes. These are common to all animals, and even, in some degree, to plants. We can imagine that these processes could be carried on if the body had no special form, if the heart, the lungs, and the stomach were only in the same general relation to each other. Indeed, such is the case in some of the lower animals. But from the fact that the heart, the lungs, the digestive and excreting organs are so essential to life, it will be seen how necessary it is to protect them and support them; and when we learn that exercise is of the greatest importance in circulation and nutrition, we can see that the body must have the force to move with rapidity and ease. To do this, it must have not only muscles for pulling, but a solid framework to which the muscles may be attached. These purposes are fulfilled in the hard or bony part of the body, the skeleton.

**The Uses of the Bones.** — In the figure (67) of the skeleton as a whole observe: —

1. The skeleton gives form to the body.
2. It supports the softer tissues.
3. It protects vital parts, as the brain in the skull, the

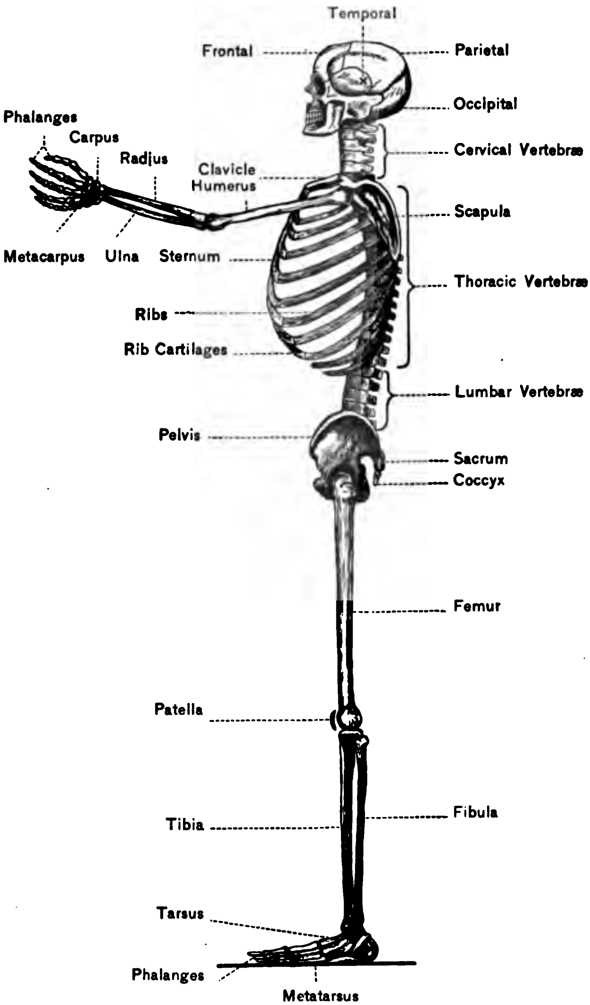



Fig. 67. — Side view of human skeleton

spinal cord in the spinal column, the heart and lungs in the thorax, etc.

4. The bones serve as levers in producing motion and locomotion.

The part that the bones play is of a passive nature; they support the tissues, protect some parts, and serve as levers on which the muscles act. We may not call the bones dead tissues, for they receive blood and grow. But the active muscles use them as a man uses a crowbar, as a mere tool.

**The Two Principal Parts of a Skeleton.** — Observe that the skeleton as a whole consists of two portions, the axial portion, consisting of a central axis, the spinal column, to which the head belongs; and the appendicular portion, the limbs and the bones belonging to them.

These are further divided into "bone groups," made up of bones in such close relation to each other that they can hardly be studied separately. Their use to each other and to the whole body can best be learned by classing them together. First among these are the regions of the spinal column, the cervical or neck vertebræ, the thoracic or chest vertebræ, and the lumbar or loin vertebræ. Below these are the bones of the pelvis. (See Fig. 67.) Above the cervical vertebræ is the skull, including the bones of the face and ear.

Articulated (jointed) to the bones of the thorax are those of the upper limbs — the shoulder, arm, and hand; and, correspondingly attached to the pelvic bones, are those of the lower limbs — the thigh, leg, and foot.

**Shapes of Bones.** — Whenever the bones of the body are needed for leverage or extension they are long, as in the legs and arms. Wherever they are needed mainly for protection, they are flat, as in the shoulder blade, the

sternum, the pelvic bones, and the parts of the skull. Wherever there is needed flexibility — as in the spine — or power of motion in all directions, as in the hand, the bones are short.

**Composition and Properties of Bones.** — For their various uses, the bones must be hard enough to protect the more delicate organs, stiff enough to keep the body upright, and tough — rather than brittle — that they may resist jarring and shocks. They must also be as light in weight as possible while fulfilling these requirements. For these purposes they have a special chemical and structural composition.

**The Chemical Composition of Bone.** — Bone is composed of mineral matter, two-thirds, and animal matter, one-third; in childhood the animal matter is in larger proportion, while in old age the mineral matter is in excess.

The mineral matter is chiefly calcium phosphate, while the animal matter is largely gelatin.

**The Weight of Bones.** — The bones make about one-sixth of the weight of the living body. When dried, they may lose half of their weight.

**The Spinal Column.** — The central part of the skeleton is the backbone, or *spinal column*. As a whole it is a column, widening toward the base, composed of a series of separate bones called *vertebræ*.

Each vertebra has seven processes, four articulating (two anterior and two posterior), two transverse, and one spinous. (See Figs. 67 *A* and *B*.)

**Articulations of a Vertebra.** — The smooth places where the articulating processes join are called *facets*. Observe on each side of the body of the vertebra a facet where the head of the rib articulated. There is also a facet on

the transverse process where the tubercle of the rib articulated.

**The Cervical Vertebræ.** — The seven cervical (neck) vertebræ have holes through their sides, or transverse processes, for the passage of blood tubes.

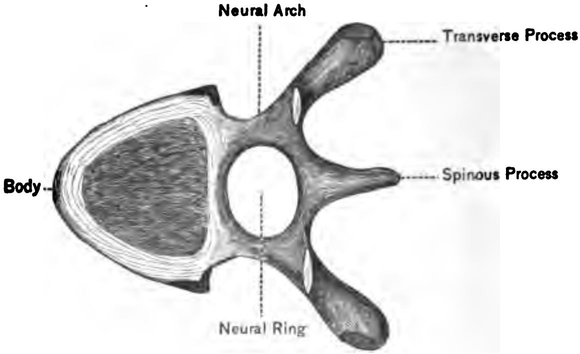



Fig. 67 *a.* — Anterior view of thoracic vertebra

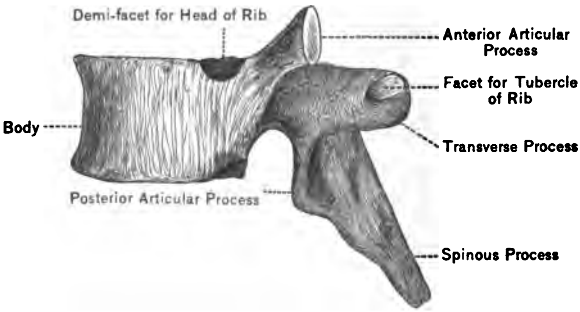



Fig. 67 *b.* — Left side view of thoracic vertebra

**Atlas and Axis.** — The first vertebra, the *atlas*, has no body. The second vertebra is the axis. It has a peg, called the *odontoid process*, which represents the body of the atlas. In shaking the head, the atlas, with the head,

turns on the axis. In nodding the head, the head simply rocks back and forth on the atlas.

**The Thoracic Vertebræ.** — The twelve rib-supporting vertebræ are the thoracic vertebræ.

**The Lumbar Vertebræ.** — The next five are the lumbar.

**The Sacrum and Coccyx.** — The sacrum is composed of five vertebræ grown together, and the remaining four are combined in the coccyx. (See Fig. 67.)

**Curves of the Spinal Column.** — View the spinal column from the side. Draw a line representing all its curves.

**Bones combine Lightness and Strength.** — The muscles make use of the bones as levers. We carry these levers with us all the time. Hence the desirability of having them as light as is consistent with the requisite degree of strength. The body follows the same law of mechanics that we use outside of the body. A hollow pillar or hollow tube has greater strength than the same amount of material in the form of a solid cylinder. The long bones of the limbs are hollow, and near their ends, where we have found that they need to be enlarged, we find a spongy structure, where lightness and strength are secured by the interlacing fibers and plates of bony material.

**Advantages and Disadvantages of Levers in the Body.** — The action of the bones of the forearm as a lever may perhaps be better understood by the following considerations: If the arm consisted merely of the biceps, suspended from the shoulder, it is evident that its only action would be a straight pull. Suppose the biceps, thus hanging alone from the shoulder, had a hook at its lower end, it could, when it shortened, lift a weight just as far as it shortened, and no farther. It could not swing the weight outward or push it upward. But from the way in which the biceps is attached to the forearm, when the muscle shortens an inch, it may move the hand a foot. Of course, the hand moves much faster, and we have a great gain in speed by

reason of this lever arrangement. But we cannot lift so heavy a weight at this faster rate, as we could at the elbow. For instance, suppose one were to carry a heavy basket with a bail handle by slipping the arm through the bail up to the elbow. Now, it is evident that the biceps is supporting the weight. If it is as heavy as can be held here, we know that we could not hold the same weight in the hand with the elbow bent at a right angle.

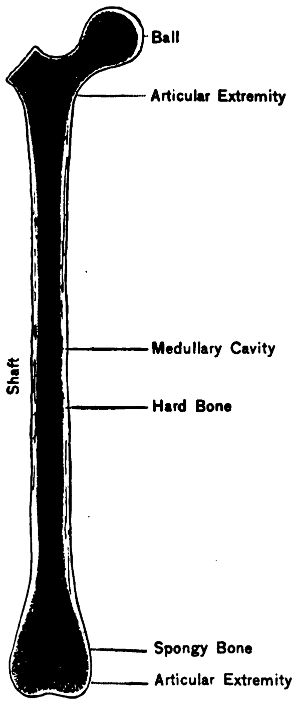



Fig. 68.—Longitudinal section of femur

**Study of One of the Long Bones.** — For this, take, preferably, a femur or a humerus. Let us suppose we have a femur.

Observe the width of the lower end of the femur, where it rests on the tibia. Suppose these two bones were as narrow at their ends, where they meet to form the knee joint, as they are at their centers, what kind of a joint would they make? Illustrate by piling up a number of spools on end; the column is more lightened than it is weakened by the hollowing out of the sides of each spool. And the central hollow of the spool does not greatly weaken it. A given weight of material has more strength when in the form of a hollow cylinder. The bones combine well two very desirable qualities, lightness and strength. If in our column of spools we place a wide rubber band around the junction of two spools, we have something very similar to the capsular ligament, which surrounds the joints.

**Joints.** — The ends of the bones, where they fit together in the joints, are covered with a layer of smooth, elastic, whitish or transparent cartilage. The motion in the joints is made still more easy by the *synovia*, resembling white of egg. The ends of the bones are held together by tough bands and cords of ligament, a form of connective

tissue very much like tendon. Bones are closely covered by a tough coat of connective tissue called the *periosteum*.

All these structures can easily be found by dissecting a sheep shank gotten from the butcher, or in the hind leg of a rabbit.

**Classification of Joints.** — Joints may be classified according to their structure as follows: —

1. Immovable, such as the sutures between the bones of the skull.

2. Mixed, such as the joints between the vertebræ.

3. Movable, which allow free motion between the parts:

(*a*) Ball and socket, as in the hip and shoulder.

(*b*) Hinge, as in the knee and elbow.

(*c*) Pivot, as in the forearm, and between the atlas and axis.

(*d*) Gliding, as between the short bones of the wrist and of the ankle.

**Locomotion.** — Locomotion is moving from place to place and should be distinguished from mere motion. By continuing such observations as we made when we began to study our motions, we can analyze and understand many of the common movements which we habitually make.

**Standing.** — Although we are not ordinarily conscious of the fact, when we are standing still we are using many muscles. The accompanying figure illustrates how some of the muscles act in keeping the body upright. Our

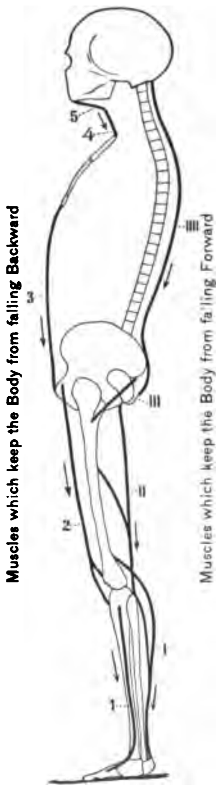


Fig. 69. — Muscles in action in standing: black lines and arrows.

weight, or, we might better say, the force of gravity, is continually trying to pull us down to the ground. The joints are all freely movable, and hence as soon as the muscles cease to act properly, in balancing against each other, we lose our equilibrium, and fall if we do not quickly regain it.

**Locomotion by Reaction.** — Take two broomsticks and place them crosswise under the ends of a board. Run along the board. This shows that the direct effort in running is to push one's support from under him. When a horse plunges forward in the mud, he only thrusts his feet farther into the mud. Our effort in progression is primarily to push the earth out from under us, and it is by reaction that we go forward. It is the same problem with the fish swimming forward by striking backward and sideways against the water, and with the bird beating downward and backward upon the air.

**Walking.** — In walking, we lean forward, and if we take no further action, we fall. But we keep one foot on the ground, pushing the body forward, or the other leg is flexed and carried forward to save us from the fall. We catch the body on this foot, and repeat the action. To show how we are really repeatedly falling and catching ourselves, recall how likely one is to fall if some obstacle is placed in the way of the foot as it moves forward to catch the weight of the body.

**Running.** — In running, the action is more vigorous. The propulsion by the rear leg is now greater. It gives such a push as to make the body clear the ground, whereas in walking the rear foot is not lifted till the front foot touches the ground. But in running there is a time when both feet are off the ground.

**Levers.** — The essentials of a lever are the point about which the lever turns, called the *fulcrum*, the place where the power is applied, called the *power*, and the part to be

moved, called the *weight*. In the body, the fulcrum is some joint, the *power* is the place where the muscle is attached, and the weight is the part to be moved. (See Fig. 71, page 184.)

**Kinds of Levers.** — In flexing the forearm, the weight is the hand or the hand and what is in it; the fulcrum is the elbow joint; and the power is the point where the tendon of the biceps is attached to the radius. This kind of lever is what the books call a lever of the third class. The

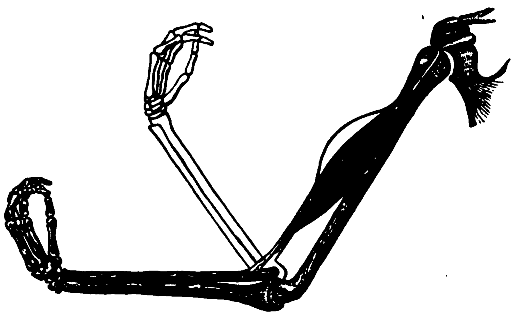
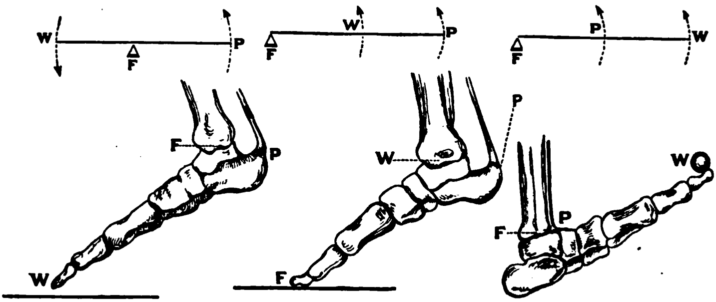


Fig. 70. — The shortening and thickening of the biceps muscle in raising the forearm

triceps, on the back of the arm, pulls on the projection of the ulna (the inner bone of the forearm when the palm is up), back of the elbow. The elbow is here, also, the fulcrum, and the hand (or the object to be pushed by the hand) is the weight. This kind of lever, where the fulcrum is between the power and the weight, is called a lever of the first class. In raising the weight of the body by standing on tiptoe, we use a lever of the second class. Here the ball of the foot is the fulcrum. The weight is the weight of the whole body, resting on the ankle joint, while the power is the calf muscle. We may find many examples of levers in the body if we look for them.

**Kinds of Levers shown by the Foot.** — The different classes of levers may be further illustrated by different motions of the foot. In tapping the toes on the floor while the heel is lifted, or in pressing down the ball of the foot while running the treadle of a sewing machine, we have an example of a lever of the first class. In raising the weight of the body on tiptoes, or as the foot is used in taking each step, the foot is used as a lever of the second class. When




(1) Tapping on floor (2) Rising on toe (3) Lifting weight

Fig. 71. — Three kinds of levers as shown by the foot
P — *Power* W — *Weight* F — *Fulcrum*

one lifts a weight with the toes, the foot is used as a lever of the third class. These three classes of levers are illustrated in the accompanying figures.

**Hygiene of the Bones.** — As the skeleton is the framework and means of protection of the body, it is closely connected with the most delicate organs; for example, the brain, the lungs, and the larger arteries. Any malformation, therefore, may not only injure the bones and make them less efficient tools for the muscles, but may actually cause them to press upon the vital organs, injuring these beyond repair.

Especially is this the case in the vertebræ, through the

openings of which pass the spinal nerves and many blood vessels. Any deformity or displacement in the spinal column may thus interfere with the normal action of the organs to which the spinal nerves, veins, and arteries extend. In youth, when the bones are most flexible, careless postures or strains from overlifting may bring deformities which impair not only the vigor and beauty of the body, but also lay the foundations for disease.

Sometimes the bones of children are deficient in mineral elements, and are unduly soft and flexible. This condition indicates a disease called *rickets*. Even if the bones are normal, children should not be encouraged to walk early, as bow-legs may result. Most bow-legged persons seem to be active, and probably their muscles developed faster than the bones. Constrained positions or excessive use of special groups of muscles may result in lateral curvature of the spine. The height of seats and desks should be carefully looked after.

**Effects of Alcohol.** — Alcoholic drinks are particularly injurious to the young. They interfere with proper nutrition and thus retard growth and development. In Europe a few years ago the examinations for military service revealed the fact that the stature of the young men was decreasing, and in order to secure the required number of recruits it was necessary to lower the standard. Official investigation was made to ascertain the cause, and experts reported that it was largely due to the use of alcohol.

**Sprains and Dislocations.** — Sprains and dislocations are injuries to the joints, and often bring more serious results than a broken bone. There should, as a rule, be complete rest until the part can be used without pain. Otherwise a stiffened joint may result. Hot water applied

to a sprain or bruise promotes circulation and prevents discoloration. But if there is inflammation, cold water should be applied. Bandages may be needed for support.

## TABLE OF THE BONES

| | | |
|---|---|---|
| HEAD (28) | *Skull* (8) | Frontal (forehead). |
| | | 2 Temporal (temples). |
| | | 2 Parietal (side). |
| | | Occipital (posterior base). |
| | | Sphenoid (base). |
| | | Ethmoid (base of nose and between eyes). |
| | *Face* (14) | 2 Superior maxillæ (upper jaw). |
| | | 2 Nasal (bridge of nose). |
| | | 2 Malar (cheek). |
| | | 2 Lacrymal (inner front corner of orbit). |
| | | 2 Turbinated (within nostrils). |
| | | 2 Palate (posterior hard palate). |
| | | Vomer (nasal partition). |
| | | Inferior maxilla (lower jaw). |
| | *Ears* (6) | Malleus (hammer). |
| | | Stapes (stirrup). |
| | | Incus (anvil). |
| CERVICAL REGION (8) | | 7 Cervical vertebræ (neck). |
| | | Hyoid bone (base of tongue). |
| THORAX (37) | | 14 True, 6 false, 4 floating ribs. |
| | | 12 Thoracic vertebræ (back). |
| | | Sternum. |
| UPPER EXTREMITIES (64) | *Shoulder* | Clavicle (collar bone). |
| | | Scapula (shoulder blade). |
| | *Arm* | Humerus (arm). |
| | | Radius, Ulna (fore arm). |
| | *Hand* | 8 Carpal (wrist). |
| | | 5 Metacarpal (palm). |
| | | 14 Phalanges (fingers). |
| LUMBAR REGION (5) | | 5 Lumbar vertebræ (loins). |
| PELVIS (4) | | 2 Innominata. |
| | | Sacrum. |
| | | Coccyx. |

| | | |
|---|---|---|
| LOWER EXTREMITIES (60) | *Thigh* | Femur. |
| | *Leg* | Patella (kneepan).<br>Tibia (large bone).<br>Fibula (outer bone). |
| | *Foot* | 7 Tarsal (instep, heel).<br>5 Metatarsal (arch).<br>14 Phalanges (toes). |

## QUESTIONS FOR REVIEW

1. What are the general functions of the bones?
2. How are their shapes adapted to their special uses in different parts of the body?
3. Why wouldn't it be well to have solid bones?
4. What is the chemical composition of bone? Is it the same throughout life?
5. Are the bones larger or smaller at the joints? Why?
6. What are the different kinds of joints in the body?
7. Would the hip joint be a good kind to have in the fingers? the finger joints in the shoulder? Why?
8. What is the number of the vertebræ? In what groups are they classified?
9. Is the spine flexible? Why wouldn't it serve us better to be one continuous bone?
10. What is cartilage? Is there any in the spine? Of what use is it there and elsewhere?
11. Speak of the relation of the muscles to the bones.
12. What is a lever? How are the bones used as levers? To what advantage?
13. Discuss the topic, Hygiene of the Bones.
14. What are some of the dangers to, and diseases of, the bones?

## EXERCISES

NOTE. — Isolated bones, or bones in the skeleton, are examined to learn how they are suited for motion, support, jointing, and protection of organs of the body. Give your reason for the statement made after your examination of several kinds of bones.

*The Structure and Functions of Bones.* — 1. *Kinds of Bones:* In the skeleton, or from separate bones, tell where examples of each of

the following bones according to form are found: (1) long bones; (2) short bones (not longer than twice their diameter); (3) flat bones; (4) irregular bones. Try to name the function of each kind in a general way, using some expression similar to the following: protection, support, jointing, motion, levers. In talking about bones, use common names, as hip bone, collar bone, etc.

2. *Structure of Bones.* — A section of long bone showing the structure is now examined. The stiff tube is the shaft of the bone. Learn about the mechanical principle involved. How does the shape of the end differ from that of the shaft? The ends are for articulation with other bones. Notice, in sections, how these ends are lightened. Make all these points in a descriptive paragraph of your own.

3. *Microscopic Structure of Bone.* — Hold a mounted cross section of bone up to the light and examine with a hand lens. The solid part of the bone will be seen to be pierced by many small holes (or if the holes are filled, they will appear as black spots). These are the cross sections of the haversian canals, through which run the blood tubes, mainly lengthwise through the bone.

Examine the section under the microscope, using a half-inch objective. The bony matter will now be seen to be arranged in circles, lamellæ, around the Haversian canals, somewhat like the rings seen on the end of a log.

Between the rings are circles of elongated dark dots. These are lacunæ cavities in which lay the live-bone corpuscles which built up the bone. The bone was, at first, cartilage. Later, mineral matter was deposited, forming true bone.

Now examine the section under a one-fifth-inch objective. From the lacunæ there run out, in every direction, little crevices, appearing as fine black lines. These are the canaliculi. Through the Haversian canals, lacunæ, and canaliculi the nourishing materials of the blood reach all parts of the bone.

4. *Kinds of Joints.* — Locate the following joints: ball-and-socket joint, allowing motion in a half-sphere; hinge joint, allowing motion in but one plane; pivot joint, allowing a twisting or turning motion much less than a half-sphere. To find illustrations of these, examine the 1st, 2d, and 3d joints of the fingers, the elbow, and the shoulder joint.

5. *Functions of Bones.* — To learn the use of hard mineral and

tough animal matter in bone: A piece of long bone, that has been kept in a 10 per cent solution of acid for several days, is examined. It is to be compared with a bone that has been charred. The acid has removed the mineral matter. What is left? Of what use does the mineral matter seem to be? What desirable quality does the animal matter give to the bone? What would be the danger if bones were mostly or wholly mineral matter?

6. To learn why the biceps muscle has to pull more than the weight it lifts in the hand: Some member of the class is to bring a spring balance to represent the biceps muscle and another is to make a stick to imitate the forearm, with two holes bored 12 inches apart. Then the two may set up the balance and stick in the open end of an empty box, to represent the work of the forearm. The hook of the spring balance should be placed in a notch 1½ to 2 inches from the elbow joint, a weight should be hung by a wire hook in the end of the forearm, and the nearest whole number on the spring balance is read. How many pounds pull is indicated on the balance?

Or approximate results may be obtained in the following way: In Fig. 70 measure with a ruler approximately the distance (*a*) of a weight in the hand; (*b*) the distance of the attachment of the biceps muscle from the joint. How many times farther is the weight from the joint than is the muscle? What is the ratio between the work of the muscle and the weight lifted? Why does the muscle have to pull more than the weight lifted? From the preceding answer solve —

**Problems.** — 1. How much does a muscle pull to lift a 5-pound dumb-bell in the hand? 2. How much will a 10-pound basket on the middle of the arm pull on the muscle? 3. How many inches from the joint should we place a 5-pound basket to pull 10 pounds on the muscle?

## CHAPTER XI

### THE MUSCULAR SYSTEM

**Introductory.** — Given the body, with perfect vital organs, well-formed and well-knit bones, and a healthy nervous system, it would still lack a necessary mark of power and efficiency, the ability to move. Plants stand rooted in one place and live as best they can in what the soil, the winds, and the rain bring them, but the characteristic of animal life — except in lower forms — is motion.

Without the skeleton to give form and leverage our movements would be slow, and without the nerves we could not direct our movements, but without muscles we could not move at all. The muscles, then, are the parts of the body whose one function is to produce motion.

**Two Kinds of Muscles in the Body.** — You *will* to *move* your arm to reach something that you wish. Such movements, and all others that are under the control of the will, are called *voluntary* motions. They are brought about by *voluntary* muscles. It would be well to make a list of all the groups of voluntary movements such as are made by the muscles of the arms, the eyes, the foot, etc. We may discover that these are mostly *external* muscles and movements.

The will cannot stop or start the movements of the heart or the stomach, yet the movements of these organs are also due to the contraction of muscles. These, and the muscles of all the blood vessels, of the intestines, of the bronchioles,

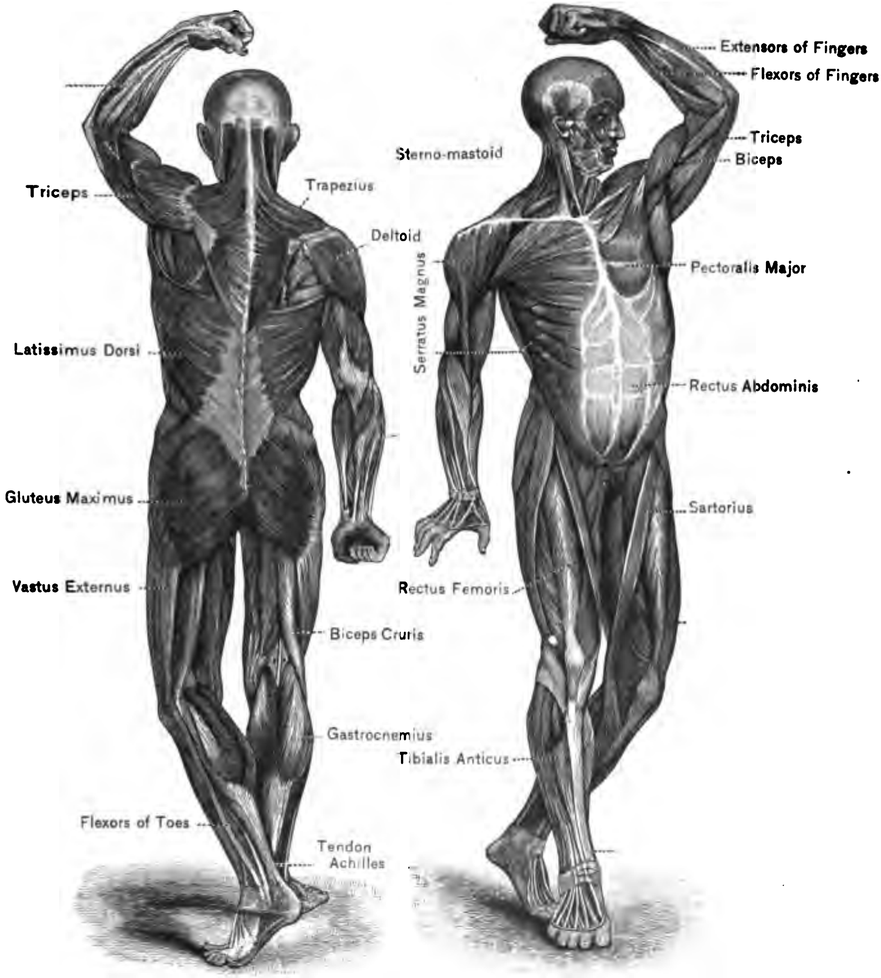



Fig. 72.—Back and front views of important muscles

and of some glands are, therefore, called *involuntary* muscles. They may be said to be internal muscles.

These names are not very scientific, but serve to call attention to two divisions under which most muscles fall. The voluntary muscles can be made to act irregularly and very quickly, while the involuntary muscles act slowly and sometimes rhythmically, *i.e.* at equal intervals of time. Such are the heart muscles, and those of the ureters and intestines, producing the so-called *peristaltic* movement of the latter.

**The Action of all Muscles.** — From the exercises at the end of the chapter we learn that muscles shorten. This is the primary and universal action of all muscle fibers that compose the larger layers or bundles of muscles. It is important to understand that muscles shorten or contract without first being stretched. In this way they differ entirely from rubber bands with which they are sometimes compared. The band can do no work by itself, but can only recoil about as much as it is stretched. The muscle, on the other hand, does work by shortening, furnishing its own energy for contraction — the muscular energy.[1]

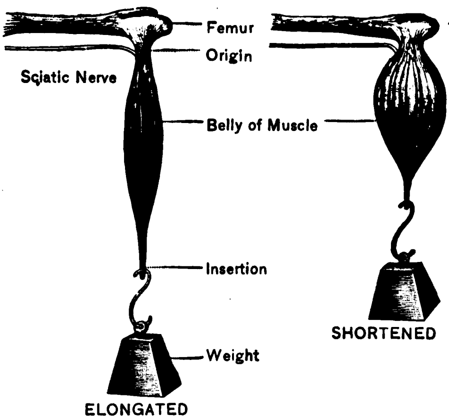


Fig. 73. — Action of the calf muscle of the frog, showing shortening and thickening at the same time

[1] It is to be remembered that contractility is a property of living protoplasm, of which muscle fibers (cells) are composed. (See Chap. I.)

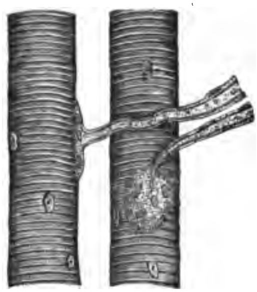


Fig. 74. — Two striated muscular fibers, showing the terminations of the nerves.

This it does by slowly oxidizing or slowly burning the carbohydrate food in the lymph that surrounds the muscle cells, *i.e.* the fibrils, thus producing heat. The heat makes the fibrils absorb water suddenly, and so they swell, shortening and thickening.[1]

**Kinds of Muscle Fibers.** — The fibrils of involuntary muscles are generally spindle-shaped and microscopic in size. They usually form a circular sheet in the walls of such hollow organs as the blood vessels, the digestive tube, etc. The heart is an exception. In voluntary muscles bundles of fibrils (cells) are sometimes two inches long, but so delicate that a single one would be scarcely visible to the unaided eye.

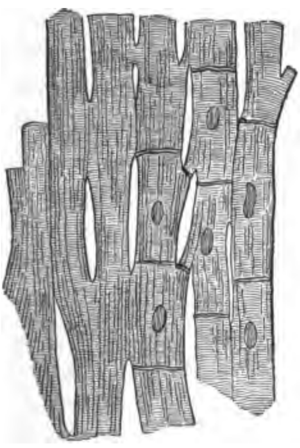


Fig. 75. — Muscular fibers from the heart, magnified, showing their cross striæ, divisions, and junctions (Schweigger-Seidel.)

The nuclei and cell-junctions are only represented on the right-hand side of the figure.

**Plain and Striated Muscle Fibers.** — Under the miscroscope voluntary fibers show a delicate cross-striping or hatching, and on this account have been called *striated* muscles, or merely "striped muscle" (Fig. 74). To contrast with these, the involuntary muscles are also called *plain* muscle fibers. It was stated above that heart muscle is an exception; its

[1] This explanation is given by some of the best physiologists.

muscle fibers are striped, yet cannot be controlled by the will, as is well known. They are therefore involuntary. Note also the peculiar shape of heart muscle fibers in Fig. 75.

**Summarizing.** — (1) We usually speak of one kind of muscles as *external* or *skeletal*, voluntary, cross-striped; (2) of the other kind as *internal*, involuntary, and plain.

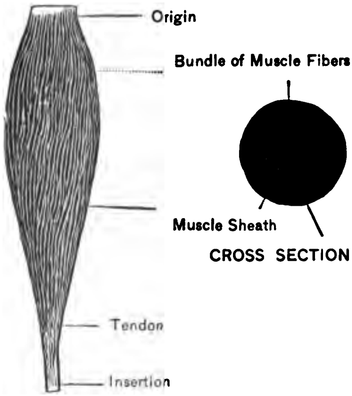



Fig. 76. — The structure of muscle.

**Structure of Muscle.** — Chipped beef shows well the structure of muscle. The white network is the connective tissue. In the meshes is the red muscular tissue. The partitions which run all through the muscle are continuous with the muscle sheath, and both are continuous with the tendons at the ends of the muscle. In fresh muscle the sheath and the partitions are nearly transparent, and are not easily seen. When the meat is cooked or salted, the connective tissue becomes white and opaque.

**Imitation of Structure of Muscle.** — A good way to represent the structure of muscle is to take a number of pieces of red cord to represent the muscle fibers. Wrap each in white tissue paper; this represents the individual fiber sheath. Lay a number of these side by side; wrap all in a common sheath; let the tissue paper project beyond the threads, and here compress it into a compact cylinder; this last corresponds to the tendon.

**Connective Tissue and Muscle Fiber.** — If all the muscular tissue were removed from a muscle, the sheaths and

partitions would remain just as they do in a squeezed lemon or orange. The connective tissue forms a framework for all the soft tissues of the body, and if their working cells were removed, the connective tissue would remain and show more or less completely the form of the part. Connective tissue, therefore, may be called the skeleton of the soft tissues. Muscle consists, then, essentially of a collection of soft, transparent tubes, filled with the semi-fluid muscle substance. By scraping the surface of a steak with a dull knife the muscle substance may be obtained, leaving the connective tissue. This is a good way to get the nutritious part of beef for an invalid.

**Other Properties of Muscles.** — Normally, all muscles are slightly contracted; it is not correct to say stretched, since there is no force pulling their ends apart. This contracted muscle condition, "muscle *tonus*," is believed to be caused by nerve impulses constantly coming to the muscle fibers, since, when such nerves are severed, *tonus* is lost. From this it is easily learned, too, that practically all normal contractions of muscles are caused by nerve impulses or messages, as all muscles except the heart are supplied with fine endings of nerves. A muscle cannot be kept shortened for any great length of time. If one holds his arm out horizontally as long as possible, he soon feels fatigue.[1]

**Muscle Shortening.** — A muscle may be made to shorten one-third of its length, but probably never shortens that much in the living body. It has been shown that muscles do their work by pulling — they cannot push. Where a

[1] While muscles may become exhausted — fatigued — by artificial stimulation until their glycogen is all used, ordinary fatigue is due to lack of stimulation. See Chap. XII, Nervous System.

push is needed, *e.g.* with the foot or hand, it is accomplished by the pull of an opposite muscle.

**Alternate Action of Flexors and Extensors.** — If we consider the biceps and triceps of the arm, we see that they are compelled to act alternately if they would do effective work. They might both shorten at the same time, and are made to do so in such an attempt as that of holding the arm rigidly bent at a right angle; as, for instance, in wrestling "square hold," in which case one wishes to prevent his opponent from either pushing or pulling him. But while the two muscles act, no motion is produced. When the flexor shortens, the extensor lengthens, and *vice versa.*

These properties of muscles are sometimes referred to as laws of muscle action.

**Symmetrical Development of the Muscles.** — The muscles of the two sides of the body are the same in number and arrangement. At birth they are probably about equal in size, weight, and strength. Most persons early become right-handed, and the greater use of the right hand and shoulder makes the muscles of this side larger and heavier. The muscles pulling on the bones slightly modify them in shape. The whole body may become noticeably unsymmetrical. Most persons step harder on one foot than on the other, as shown by the sound of the footstep, and as shown by the constant wearing of one shoe sole or heel faster than the other. In many persons one shoulder is habitually carried higher than the other. Symmetrical development should be carefully sought, and any tendency to a one-sided development should, so far as possible, be avoided. We should use the left hand more. There are many advantages in being able to use either hand. In carving, in shaving, in bandaging, in administering medi-

cine, it may be necessary to use the left hand skillfully. The pianist and the harpist use the two hands about equally, while the violinist puts much more skill into his left hand. Trainers of athletes often begin by developing the left side of the body till it equals the right in size and strength.

**Some Prominent Muscles.** — The deltoid on the shoulder is a noticeable muscle. The biceps and triceps have already been studied. The calf muscle is one of the thickest and strongest in the body. The great muscles of the rump are needed to raise and hold the body up. On each side of the front of the neck is a muscle that extends down to the top of the breastbone.

**Muscles of Expression.** — The facial expression is due to the action of the muscles of the face, which in turn are under control of the cranial nerves. The habitual position becomes somewhat "fixed," so it is true that character is often shown by "the looks." Cultivation of happy thoughts therefore tends to make one better looking.

**Muscles and Fat.** — Fat fills in space between muscles, and, if abundant, forms a layer over the muscles. One notable instance is the hollow triangular space between the muscles of the cheek. If there is very little fat, a depression is seen, forming the "hollow cheeks." But an abundance of fat makes a corresponding elevation.

**Rigor Mortis.** — *Rigor mortis* (death stiffening) is a muscular rigidity due to the coagulation of muscle plasma. It usually sets in not long after death, the time of its appearance and its duration being variable.

**Relation of the Muscles and the Bones.** — As has been said, those muscles which are attached to the bones are called skeletal muscles. They act upon the bones as levers, giving to motion strength, quickness, and precision. With-

out bones our motions would be like those of an earthworm or slug, slow and uncertain. The muscles, acting through the bones, can lift a weight that would crush the muscles if laid directly upon them, while a bone, able to support a heavy weight without being crushed, has no power in itself.

After examining Fig. 70, feel the biceps of your arm and show the points of its *origin* and *insertion*. Note that its thickest part is opposite the most slender part of the bone. But at the enlarged end of the bone the muscle has narrowed to a slender tendon, which passes over the joint to be attached to the next bone, thus giving more slenderness, flexibility, and freedom of motion to the joint. The muscle which closes the mouth, as in pursing up the lips, is not attached to any bone, but in shortening reduces the aperture. It is called a sphincter muscle.

**Sculpture and Anatomy.** — The sculptor needs to be a thorough student of anatomy, so far as the bones and muscles are concerned. If he knows the muscles thoroughly, he can model them naturally and accurately. Otherwise his work cannot be truly good.

## Hygiene of the Muscular System — Exercise

**How Exercise is Beneficial.** — The full significance of the benefits of muscular exercise can better be understood after we have studied the blood and its work in the tissues of the body generally. Now we can comprehend how exercise stimulates the cells to activity, renews the lymph around the cells both by quickening the blood flow and by pressure on the lymph tubes; how the glands of excretion are set to work more actively, and the more rapid blood stream brings away the material to be thrown out.

**Exercise for General Health.** — Exercise is not merely for the muscles. It quickens the action of the whole body

by increasing cell activity. It helps clean out the system and clear the brain as well. We read Blaikie's admirable book, *How to Get Strong*, and learn not merely to strengthen the muscles, but how to get strong to do the work we have to do daily, how to feel well every day, how not only to do our work, but to do it gladly, and with a little extra good cheer that may radiate from us and inspire others. We have no right and no need to carry the sour visage of a devitalized body. Good health is attainable, and ought to be attained, by nearly all. Attention must be paid to the laws of our being. It takes some effort, mental as well as physical, to adopt and observe regular hours for exercise and relaxation and to be careful in diet.

**Nature's Rewards and Punishments.** — But nature rewards for obedience by the delight of a healthy body; and she never forgets and never forgives, nor fails to punish, every violation of every one of her laws. Nature makes no threats beforehand. She does not even tell us her rules. But we may find what they are by careful observation.

**Exercise prolongs Life.** — Many men would live longer, feel vastly better, and do greater good in the world if they would take regular and systematic exercise or recreation (and this should be, literally, re-creation). It is a short-sighted policy to say, "I cannot afford the time." Not to take time for exercise is to mortgage one's health. Lord Derby says, "He who does not take time for exercise will have to take time for illness." The latter half of every person's life ought in many respects to be by far the most productive of good. But many cut off this half, or render it less productive, through breaking down in health as a consequence of violating the laws of hygiene. Thus one defeats his own ends in life, and robs the world of the debt

he owes it, that of returning to it, in his riper years, something for the help it gave to him in his early years while he had not yet reached the fullest mental maturity. It is sad enough that so magnificent a structure as the human body must perish and become part of the common clay. But it is infinitely more sad to think that it has not fulfilled its purpose when the end comes in what should be mid-career. Each of us should leave the world better than he found it, and our ability and opportunities for doing this increase as we reach middle life.

**Forms of Exercise.** — In selecting the kind of exercise the old lines fit well: —

> "In whate'er you sweat, indulge your taste;
> The toil you hate fatigues you soon,
> And scarce improves your limbs."

Of course this does not mean that a boy should refuse to saw wood because he dislikes it, and spend all his time playing ball. But for older persons, especially those of sedentary occupation, exercise that exhilarates is far more beneficial than that which is not enjoyed. One may take a walk and carry all his cares and anxieties with him, but he is not likely to think of such matters when playing tennis with a good opponent. Whether it be horseback riding, golfing, cycling, boxing, boating, skating, or other form of exercise, choose, whenever a choice is possible, that which you thoroughly enjoy. Exercise should be taken outdoors whenever possible. The gymnasium is a substitute in bad weather.

**Games of School Children.** — Most of the games of school children are excellent kinds of exercise. Cases have been reported of injury from excessive skipping the rope. But in moderate degree it is a good exercise. Tag,

snowballing, racing, the various games of ball, jumping, hopping, and other games may be played on the school grounds.

**Tennis.** — Tennis is a fine game, and suitable for girls as well as boys. It has the great advantage over baseball that it does not require large grounds (which often means going some distance from the school grounds or from home). Two can make up a game, and a little time can be better utilized than with the games requiring more players. The exercise, too, is more evenly distributed. There is no long waiting, as in some games, but a constant interchange of play, active but not severe, with practically no danger of injury.

**Baseball and Football.** — At present basket ball is the more popular game, but for those who can pursue the more vigorous games of baseball and football they are admirable, and should not be objected to because occasional injury comes from them. No vigorous exercise is wholly unattended by risk, though it is usually slight when the proper care is used. All these games calling for great activity and strength develop manly qualities in boys, and do much to make them active, fearless men, men who in time of danger have not only strength and endurance, but well-trained muscles, cool heads, and brave hearts, men who know what to do and how to do it in an accident, as at fires, upsetting of boats, etc. A few strong, cool-headed men, by their presence of mind, may stop a panic and save many lives when there is an alarm of fire which proves false — as often happens. The Duke of Wellington said that it was on the football fields of Eton and Rugby that the battle of Waterloo was won.

**Boxing.** — Boxing is a splendid exercise. It calls into

play nearly every muscle of the body. Many pieces of apparatus in a gymnasium are for the especial purpose of working certain muscles. But a set of boxing gloves may be said to contain a whole gymnasium. Many kinds of work in a gymnasium are likely to be overdone, especially if not under the direct supervision of a good director. One may overlift or overstrain himself. But in boxing there is little tendency in this direction. Boxing makes one quick on his feet, trains to quick movements of the arms, trains the eye, keeps the body in an erect position, and especially develops the muscles of the legs and back. Boxing brings out the chest and shoulders. It develops the "wind," and keeps one in constant action. It teaches control of the temper more than almost any form of exercise. It develops a degree of self-reliance that is worth much. Instead of developing a tendency to become involved in quarrels, it prevents getting into such disgraceful affairs. The man who knows that he can defend himself when it becomes necessary is far less likely to pay serious attention to idle bluster and slight provocation than one not so trained. And it may prove valuable to know how to defend one's self from the attack of a ruffian, or bully, or drunken brute, or other infuriated animal. The coolness of head, the quick judgment, and prompt action of a trained boxer frequently save one from serious injury, and add not a little to personal comfort. Like tennis, boxing calls for little apparatus, little space, and only two persons. In many places where ordinary gymnasium work is out of the question, boxing is available. It is indeed a "manly art," and the doctrine taught in *Tom Brown's School Days at Rugby* is as wholesome as can be given to boys to make them strong and active, to give them physical and moral health.

**Bicycling.** — This is an excellent exercise, as it is in the open air and exhilarating. There is danger of over-exertion, and it is bad for one to yield to the temptation to make long runs. There is danger of overtaxing the heart. The handle bar should be adjusted to allow a fairly upright position. The saddle should be such as not to sustain the weight on the perineum.

**Exercise for Middle-aged Men.** — For men in middle life, in most cases, milder exercises are preferable, such as golfing, fishing, and horseback riding. Every person should have some form of exercise that takes him into the open air daily. The English are more given to their "constitutionals" than their American cousins, and are the better for it. Doubtless if we paid more attention to these matters we should lose something of our national reputation as a "nervous people." English women are noted walkers, and do not seem to pride themselves on the smallness of their feet. The signs of the times would appear to show that we are improving in this respect. Probably Americans make too much use of street cars. Walking is the cheapest exercise, and every one can afford to take it. For those who can afford it, horseback riding is admirable. As Dr. Holmes expressed it, "Saddle leather is in some respects even preferable to sole leather; the principal objection to it is of a financial character." Lord Palmerston said, "The outside of a horse is the best thing for the inside of a man." Perhaps livery bills would prove cheaper and more agreeable than doctors' bills.

**Riding and Rowing.** — Riding is one of the most exhilarating of all exercises, especially with a well-trained horse. His quick obedience to the rein, so that he canters or walks or trots as the rider wills, makes him like an intelligent companion, while the motion is said to invigorate more muscles than any other form of exercise, even that of walking. Rowing must not be overlooked as one of the most beneficial exercises, since it calls into play most of the muscles and insures fresh air amid interesting and often beauti-

ful surroundings. Swimming has the double advantage for exercise and for life-saving.

## Ailments of the Muscular System

**Rheumatism.** — This is one of the most common chronic ailments. Though many causes for this disease have been assigned, such as fatigue substance, accumulated acid, etc., the definite cause has not yet been located nor any definite treatment formulated. It is, however, agreed that the accumulation of waste substances in muscle faster than the blood can remove them is the cause of much ordinary muscular pain, called rheumatism. Improving the circulation and moderating the exercise that entails such pain are obvious remedies. The aching of an arm or shoulder is temporarily relieved by movement of the member, thus quickening the sluggish circulation.

**Convulsions.** — These spasmodic actions are due to disordered action of the muscles, and, further back, to the disturbed action of the nervous system that controls the muscles. Various disturbances, such as indigestion, may by reflex action bring on convulsions.

**Tetanus**, or lockjaw, is usually mentioned as an affliction of the muscles. It is really due to the tetanus germ, whose poison causes the nerves to goad the muscles to complete exhaustion and the death of the patient. The use of salt solution to irrigate the tissues and wash out the poison has been tried. An antitoxin has been successfully used.

*Trichinosis* is an inflammatory condition of the muscles due to boring trichinæ. It has been treated of under Dangers from Food.

**Alcohol and Muscular Energy.** — Alcohol does not increase the energy of the body so far as muscular work is

concerned. Repeated experiments have been made which show that power to do muscular work is diminished as the result of taking alcohol. The person may, and often does, *feel* stronger, but the feelings are neither a sure test nor a safe guide. As one writer says, the drunken man thinks he is strong enough to hold two men, whereas he needs two men to support him in his weakness. Test of ability to do work shows the weakening effect of alcohol. It was formerly supposed that when men were called upon to perform unusually hard work, they needed the sustaining power of alcoholic liquor, and such drink was furnished to men engaged in harvesting, etc. This belief has been thoroughly disproved.

The apparent liveliness of the tipsy person, and his more or less violent gesticulations, are no sign of added strength. We all know that restlessness and nervous activity are often a sign of weakness and not of strength.

**Alcohol and Training.** — It is a significant fact that men who are training for athletic contests (no matter what their ordinary habits or principles are) let alcoholic drinks alone. One of the famous pugilists said, "I'm no teetotaler, but when I have business on hand, there's nothing like water and dumb-bells." No schoolboy or college student can hope to keep a place on any athletic team if he indulges in alcoholic drink.

### QUESTIONS FOR REVIEW

1. What is the simple function of the muscles?
2. Classify muscles as to their location in the body, their structure, their movements.
3. What is the normal condition of all muscles? How do they act?
4. What is connective tissue?

5. What do you understand by "muscle tonus"?

6. Which is more tiresome, standing still or walking? Why?

7. If muscles could push, would it be necessary that they should be arranged to counteract each other?

8. What causes the contraction of muscles?

9. What care should be taken in developing the muscles? In exercising them?

10. Locate some of the prominent muscles.

11. Tell something of the relation between the muscles and the bones.

12. Is it necessary to exercise the muscles? Is it necessary to exercise anything *but* the muscles?

13. What are some of the best forms of exercise? Why?

## EXERCISES

1. *To illustrate Change in Shape when Muscle Works.* — (*a*) Clasp the biceps muscle in the front of the right upper arm; draw up the forearm strongly as far as possible. What changes are felt in the biceps muscle?

(*b*) Repeat the experiment, and with the thumb and finger feel the cord, or tendon, at the lower end of the muscle, just within the angle of the elbow (Figs. 71 and 72).

(*c*) Press upward under the edge of the table or lift a heavy weight from the table, feeling the condition of the muscle during the experiment. How does the contraction affect the size of the muscle? the firmness? What effect on the muscle?

2. Span the muscle, placing the tips of the fingers in the angle on the elbow, and the tip of the thumb as far as you can up the arm; again bend the arm. What change in the muscle does this show? Any muscle that bends a limb, as does the biceps, is called a *flexor* muscle.

3. *To learn the Work and Position of the Triceps Muscle.* — Clasp the back of the right upper arm and forcibly press the hand on a table. What effect on the muscle? The muscle lying along the back of the arm is the triceps muscle. It is called an *extensor* because it extends or straightens the arm.

4. *To locate the Muscles that open and close the Fingers and Hands.* — Clasp the upper side of the right forearm near the elbow; clench

the right hand quickly and forcibly; repeat rapidly. Put backs of fingers under table as if to lift it. Where are the muscles that open and close the fingers?

NOTE. — The movements seen in the wrist when opening and closing the hand are due to cords (tendons) moved by the muscles.

5. Notice the thick mass at the base of the thumb; pinch the forefinger and thumb strongly together. What changes can be seen and felt in this mass? What is it?

6. *To locate the Walking Muscles.* — Stand erect, with the heels close together but not quite touching; rise on tip toes without moving otherwise; repeat five times. Where are the muscles that lift your weight in walking?

7. *To learn the Amount of Work done by the Walking Muscles at Each Step.* — The distance of the heel cord from the ball of the foot (fulcrum), in Fig. 71, is measured. Then the distance of the ankle, where the weight of the body rests, from the fulcrum is measured. The first is one inch, the other is $\frac{3}{4}$ inch. What part of your weight does the calf muscle lift at each step you take? How many pounds?

8. *To locate the Chewing Muscles.* — (*a*) Place the tips of the fingers on the angles of the lower jaw; shut the teeth firmly on a piece of rubber or folded handkerchief, and note the bulging of the masseter muscles.

(*b*) Press the fingers on the temples; again close the jaws firmly and feel the action of the temporal muscles. What does it do?

What do we learn by the above experiments, about the length, thickness, and firmness of muscles when they contract or work?

# CHAPTER XII

## THE NERVOUS SYSTEM

**Conscious Nerve Action.** — In the opening of the chapter on the muscular system it is stated that all our voluntary movements are brought about by voluntary muscles, the initial cause being the will. The will acts by means of the brain. How can the will make muscles act when some of them — such as those of the fingers and feet — are at a distance from the brain? Of course this might be readily accomplished if there were connecting lines from the brain to all the muscles over which the will could direct the muscles when to contract.

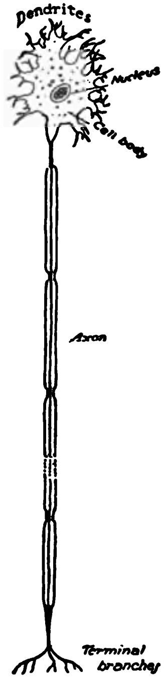



Fig. 77. — Diagram of a mon-axonic neuron (greatly enlarged except as to length). The central thread in the axon is the axis cylinder

There are such connections all the way from the brain to the extremities through the spinal cord, which serves as a sort of switchboard. From the spinal cord there are direct lines to the muscles, called *motor nerves*. These are connected by relays of nerve cells in the spinal cord, each nerve cell sending a nerve fiber toward the brain, making a complete connection.

NOTE. — The units of the nervous system are *cells*, called *neurons*. The protoplasm of nerve cells is a peculiar shade of gray. The cell usu-

ally has short, root-like projections, *dentrites*, one of which is much longer than the rest and is called the *axon* (Fig. 77). The axon is commonly called the *nerve fiber*. Nerve fibers are white because there is a fatty covering over the gray core.

**Structure of a Nerve Fiber.** — A single nerve fiber (axon) is too small to be seen by the naked eye, being only about one two-thousandth of an inch in diameter. It consists of the following parts: —

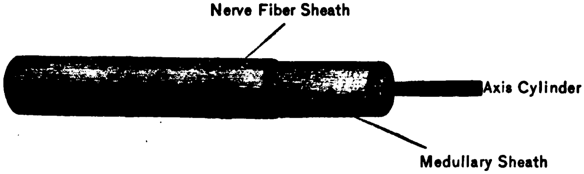



Fig. 78. — Structure of a nerve fiber (axon)

1. The *Axis Cylinder*, a central strand, or core, of semi-transparent, gray material.
2. The *Medullary Sheath*, a layer of white, oily material, around the axis cylinder.
3. The *Nerve Fiber Sheath*, a thin, transparent outer sheath of connective tissue.

**Motor and Sensory Nerves.** — We have now described the *motor* path for messages or impulses from the brain to the muscles. But unless we look at our finger or arm, how do we *know it moves*, as directed by the will? We may say that we can *feel* it, that is, we become conscious that the contraction has taken place. This means another kind of nerve line from the sensitive organ to the spinal cord, and again, by relay cells and nerve fibers of the spinal cord to the seat of consciousness, the brain. This may be called a *sensory* path for messages (impulses) to the brain.

NOTE. — Since all sensory nerves carry impulses *toward* the spinal cord or brain, they are called *afferent* nerves, from the Latin word meaning to carry toward. All motor or action nerves carry impulses *away* from the spinal cord or brain and are called *efferent* nerves. Where " nerve " is used, axon is meant.

The becoming conscious of the impulses that come to the brain over sensory nerves, *e.g.*, of pain, of a noise, or a perfume, is called a *sensation*. Only the fore-brain can have sensation; only axons or nerve fibers carry impulses. Impulses may start in any part of the body — from the will in the brain or from a pin-prick in the finger. Whatever starts a nerve impulse is called a *nerve stimulus*.

In this simple outline of conscious nerve action there are always three steps: (1) stimulus; (2) impulse; (3) sensation or action.

**Natural Nerve Stimuli.** — Natural nerve impulses that run outward are ordinarily started by the action of some nerve cell or cells, as from the gray matter of the brain or of the spinal cord; *e.g.*, a thought or remembrance to do something.

Nerve impulses coming inward may be started in several ways, ordinarily by some one of a few forces that are capable of affecting the nerve endings. A *mechanical stimulus*, as pressure, acts on the nerve endings of the skin, and starts nerve impulses which are carried to the brain and rouse certain cells to activity and give us the sensation of touch. Heat and cold start impulses over certain nerves and are called *thermal stimuli*. The vibrations known as light excite the special nerve endings in the retina but affect no other nerve endings. Sound is appreciated only by the endings of the auditory nerve. Certain gases or fine particles affect the olfactory nerve endings. Certain substances may give the sense of taste by acting on the

ends of nerves in the mouth. These are *chemical stimuli.* Different nerve endings, then, are adapted to *receiving* impressions from different forces, but the axons merely *carry* impulses.

**Nerve Impulses.** — We know but little of the nature of the nerve impulse. A feeble electric current is present in the fiber whenever the impulse passes over it, and travels at about the same rate — 100 feet per second. The electric current is thought to be due to the passing impulse, not to be the cause of the impulse. Some think the impulse is due to an oxidation started in the substance of the nerve fiber by the stimulus. When there is no oxygen present around a nerve fiber, no impulse can be started or passed over the nerve.

**Sensations.** — When the nerve impulses from the various parts of the body reach the gray matter of the cerebrum they rouse the cells here to an activity that gives us what we call sensation. It is never a sensation until it reaches this part and is properly interpreted. In the simple sensation of touch, pressure on the toes starts a nerve current or nerve impulse which runs up to the brain. The sensation is in the brain, but through the action of the brain the sensation is referred to the foot. Hence we should be careful not to speak of a sensation being carried.

**Parts of the Nervous System.** — Now that we have the correct impression that nerve paths connect every organ with the spinal cord or the brain, we are ready for the names of the parts of the nervous system, viz.: (1) the *brain and the cranial nerves* connecting the brain directly with organs, *e.g.*, the ear and the eye; (2) the *spinal cord and the spinal nerves* connecting all other organs with the spinal cord and the brain. Since our bodies are symmetrical—that

is, have the two sides alike — the nerves from both the brain and the spinal cord go out in pairs, opposite each other. (Fig. 79.) There are twelve pairs of cranial nerves, five of which come from the so-called organs of special sense, and thirty-one pairs of spinal nerves.

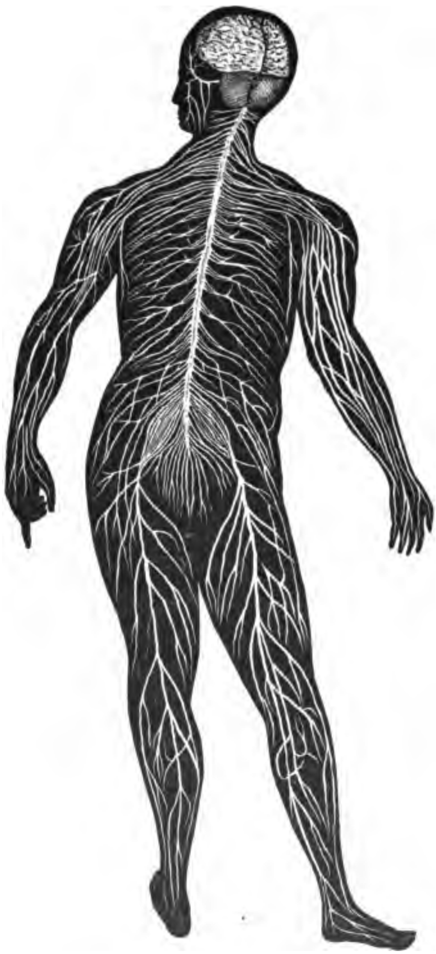


Fig. 79. — Diagram showing arrangement of nervous system

Generally, the brain and spinal cord are called the *central nervous system*, and the spinal and cranial nerves the *peripheral system*, in distinction from a sort of accessory nervous system, composed of a row of nerve centers, *ganglia*, on either side of the spinal column but in the body cavity. This is called the *sympathetic nervous system.* Sympathetic nerve fibers connect these ganglia with the spinal nerves and also with all the internal — the so-called vital — organs. (See Figs. 45, 46, and 47.)

NOTE. — The importance of the sympathetic nervous system is seen from the fact that practically all internal vital processes, such as digestion, circulation, respiration, and nutrition, are regulated by it. For example, when we begin to chew food, saliva and other digestive secretions are started, the blood vessels in the digestive glands widen to let more blood pass, and the heart beats faster. How is this accomplished? The activity of chewing and the taste of food act as

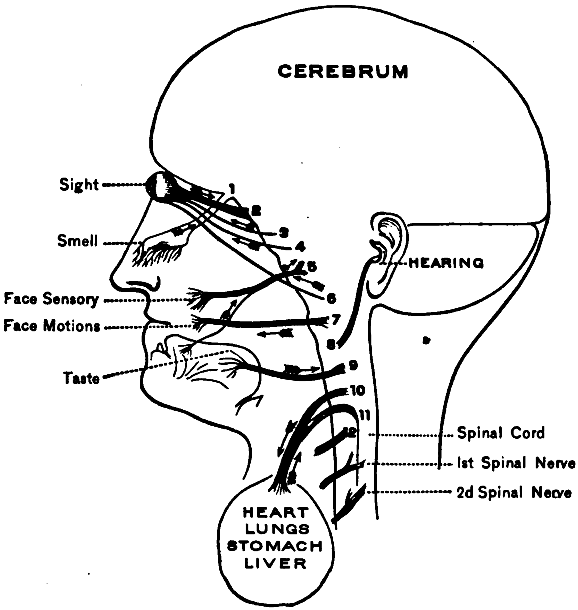



Fig. 80. — Diagram of the cranial nerves and sense organs

stimuli and start impulses which pass out over the spinal cord and nerves to the sympathetic ganglia. Here the impulses are distributed over sympathetic fibers to each of the organs named — the heart, the arterioles of the chewing muscles to give more blood, and of glands to secrete more of their special products.

**The Cranial Nerves and their Functions.** — 1. The *olfactory lobes* extend forward under the fore part of the cerebral hemispheres.

They send out the nerves of smell. See Figs. 80, 88, for all the locations of cranial nerves.

2. The *optic nerves*, or nerves of sight, join each other before reaching the brain. Only the first and second pairs of cranial nerves directly enter the cerebrum.

3. Back of the optic nerves, near the middle line, is the third pair of nerves. The third, fourth, and sixth pairs of cranial nerves control the muscles of the eyeballs.

4. The fourth pair extend up on each side into the groove between the cerebrum and the cerebellum.

5. Back of these is the larger fifth pair, the *trigeminal*. This pair supplies part of the face and sends branches to the teeth. These nerves are affected in neuralgia of the face. Besides being the nerves of sensation for most of the head and face, these nerves have motor fibers.

6. Back of and inside of the fifth pair are the sixth pair.

7. The nerves of the seventh pair are larger, and are farther back and outward. These are the *facial nerves* and control the muscles of the face and the facial expression.

8. Close to the seventh are the eighth, or *auditory nerves*, the nerves of *hearing*.

9. The ninth, tenth, and eleventh arise close together, on the sides of the spinal bulb. The ninth pair supply the back of the tongue and the pharynx, and are called the *glosso-pharyngeal* nerves. They give the sense of taste at the base of the tongue.

10. The tenth pair, or *vagus nerves*, pass down out of the brain cavity, give off branches to the pharynx and larynx, and are distributed to the heart, lungs, and stomach.

11. The eleventh pair, or *spinal accessory nerves*, arise in part from the spinal cord outside of the cranial cavity, to supply certain muscles of the neck and shoulders.

12. The *twelfth pair* of cranial nerves arise near the middle line of the spinal bulb. This pair supply the muscles of the tongue, and are called the *hypoglossal nerves*.

**The Spinal Nerves.** — Each spinal nerve arises by two roots, one nearer the back, called the dorsal root, the other nearer the ventral surface, the ventral root. These two roots soon unite to form one spinal nerve. (Fig. 81.)

On the dorsal root, just before it unites with the ventral root, is a swelling, the ganglion of the dorsal root. Like all ganglia, it is largely made up of nerve cell bodies, being a center of control rather

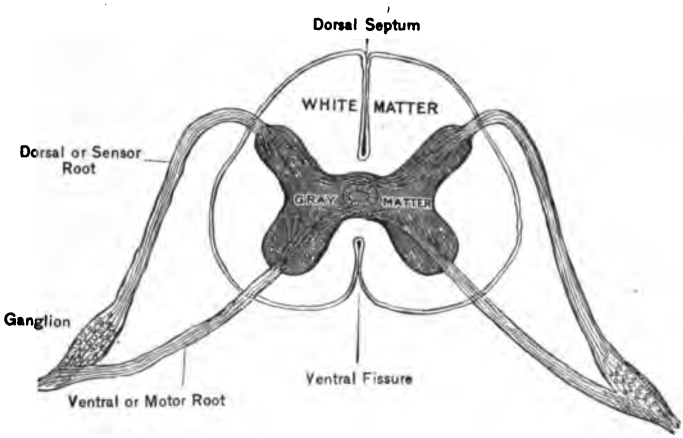



Fig. 81.—Cross-section of spinal cord

than a means of communication. This ganglion appears to control the nutrition of the adjacent nerve fibers, and is not concerned in the process of reflex action.

**Nerve Roots and their Functions.** — Observations made on animals, and accidents in the case of man, show that all the fibers of the nerves that carry currents to the muscles pass out from the spinal cord into the ventral root, and that all the fibers that carry currents inward enter the spinal cord through the dorsal root. Hence, the *dorsal* root is also called the *afferent* root, and the *ventral*, the *efferent* root. Since ingoing impulses produce sensation, the *dorsal* root is called the *sensory* root, while the *ventral* root, carrying currents outward to produce motion, is called the *motor* root.

**Effect of Stimulating a Spinal Nerve.** — Experiments have shown that if, in an uninjured animal, a nerve, or more

properly a nerve trunk, — as the *sciatic* nerve, — be stimulated, for instance, by a suitable electric shock, two effects are produced: first, motion in the parts whose muscles are supplied by the nerve; second, sensation, which is referred to the parts of the skin supplied by the branches of the nerve.

**Destination of Nerve Fibers.** — The sciatic nerve is composed of many microscopic fibers. If this nerve is traced outward, it is found to be continually subdividing, and sending small branches to the muscles, and finally in the muscles one fine nerve fiber goes to each muscle fiber. (See Fig. 82.) Many fibers go on past the muscles to the skin. We can feel in any part of the skin, and we can tell just where we are touched. These fibers from the skin, then, carry nerve impulses inward, as those going to the muscles carry impulses outward. So each spinal nerve contains two kinds of fibers.

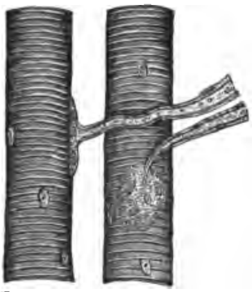


Fig. 82.—Two muscular fibers showing the terminations of the nerves

NOTE. — When the nerve divides there is ordinarily no true branching or forking, but certain of the fibers simply separate from the rest, as in the separation of the fibers in floss silk.

**Unconscious Nerve Action.** — In the first part of the chapter there was described the general working plan of the nervous system, of the nerve centers that receive and send out impulses over nerve fibers to and from all organs of the body, regulating their activity according to impulses from without or within.

But while voluntary, conscious actions are the easier

to understand, they are not the most important actions in the body to be constantly regulated by the nervous system. If the so-called vital functions — digestion, circulation, respiration, and nutrition — were left to conscious, voluntary action, they would cease while we sleep, for then the seat of conscious action, the cerebrum or fore-brain, is at rest. It must be remembered that no activities of any of the tissues of the body can go on without the regulation of the nervous system.[1]

**How the Vital Processes are Regulated.** — In the simplest vertebrate animal there is no brain — only the spinal

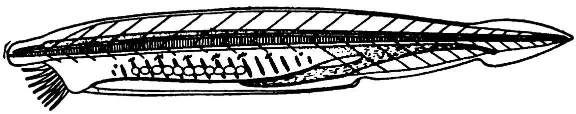


Fig. 83. — Diagram of lancelet

Above (dotted) is the nervous system; below it (cross-lined) the notochord; the mouth is surrounded by a circle of tentacles; below the notochord is a row of gill slits; the vent is near the posterior (right) end below (From Kingsley's *Zoölogy*)

cord, regulating the nervous system. In such an animal there can be no conscious or voluntary action; there can be only the activities that keep it alive — digestion, circulation, etc. And since there is only the spinal cord to regulate these, it must act as the central organ, receiving and sending out impulses. In our own bodies many organs are regulated in the same way. The nervous impulses coming from such vital organs as the heart, stomach, liver, and kidneys to the sympathetic ganglia, bringing messages of their needs, are turned back — *reflected* — by centers in the spinal cord or lower part of the brain. They are there *changed* into impulses which pass over *efferent* nerves to

[1] This is the reason why many forms of nervous disease in man are surely fatal.

make corresponding organs act. This faculty of the nervous system to regulate the action of organs without the *consciousness* or the will is called *reflex action.*

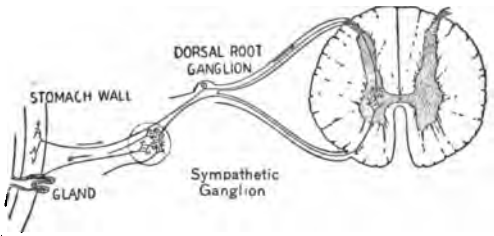



Fig. 84. — Diagram illustrating reflex action in its relation to the food canal. The nerve path in this case includes sympathetic neurons

**Voluntary and Reflex Action.** — When you prick or burn your finger, which do you do *first*, feel the pain, or jerk the finger away? Since the jerk was quicker than thought, the voluntary muscles, also, may be controlled by reflex action, especially when the stimulus is severe.[1]

**Phases of Reflex Action.** — In reflex action the current runs up the nerve to the spinal cord. The gray matter of

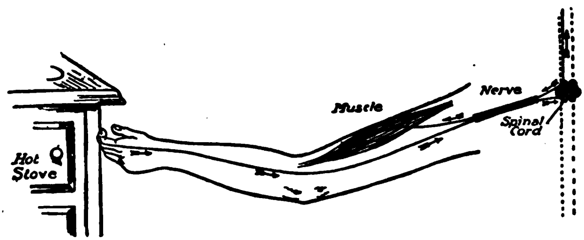



Fig. 85. — The course of a nerve message from skin surface to muscle

the central part of the cord receives the message, and sends back a nerve impulse to the muscles to make them shorten and pull the hand away from the source of injury. After this an impulse may go to the brain and the injury be felt.

[1] See page 211, where simple touch is responded to by voluntary withdrawal of the foot.

The phases of the reflex action occur in the following order: —

1. Stimulation of the nerve endings in the skin of the finger.

2. Passage of a nerve impulse up the afferent fibers to the spinal cord.

3. Reception of the impulse by a cell, or cells, of the gray matter in the cord.

4. Sending back a nerve impulse

5. Along an efferent fiber, or fibers, to

6. Muscles which shorten and move the hand.

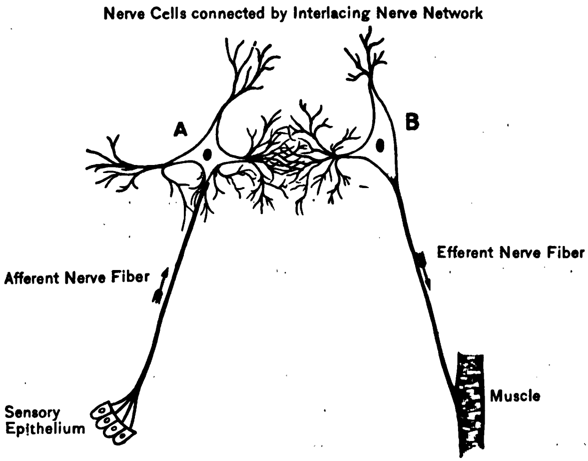



Fig. 86. — Diagram of reflex action

**Importance of Reflex Action.** — It is important, therefore, that we understand the nature of reflex action. Not only the more manifest motions, such as winking when anything comes quickly toward the eye, dodging, jumping when suddenly touched by anything hot or when pricked by a pin,

but also, as stated before, the adjustments of the essential processes of life — circulation, respiration, and digestion — are brought about through reflex action.

**Habits are Acquired Reflex Actions.** — The work of the spinal cord is that of a subordinate officer, whose duty is to relieve his superior, the brain, of many small tasks, and to afford him relief from having all the details constantly on his mind. If we learn to do many things mechanically, we save the energy of doing them by conscious effort and act of will. Whatever we do for the first time requires careful attention. What we do from habit, and cheerfully, is easily done. Hence the desirability of forming good habits, that we may, without unnecessary effort — that is, without loss of energy — do what is needed for our well-being.

Some actions become reflexes after they have been learned consciously by the brain; *e.g.*, walking becomes a reflex whose stimulus is the contact of the foot with the ground. Acquired reflexes are also called automatic.

**Function of the Spinal Bulb.** — Thus far we have considered the work of the spinal cord (1) as a pathway for nerve fibers (axons) to and from the brain, and (2) as a reflex center. It is important to understand that the upper end of the spinal cord, the *spinal bulb* or *medulla*, is joined to the rest of the brain and is considered a part of it. It is enlarged, hence its name, *spinal bulb*. From it arise all the cranial nerves except the first five pairs. The spinal bulb is also the center for the control of respiration, of circulation, of deglutition, and perhaps for many other processes. In arrangement of gray and white matter it is similar to the spinal cord, but in structure more like portions of the brain.

**The Functions of the Cerebellum.** — Next above the spinal bulb or medulla is a larger — though not the largest — portion of the brain, — the *cerebellum*. It has its gray matter on the outside in the form of fine transverse ridges.

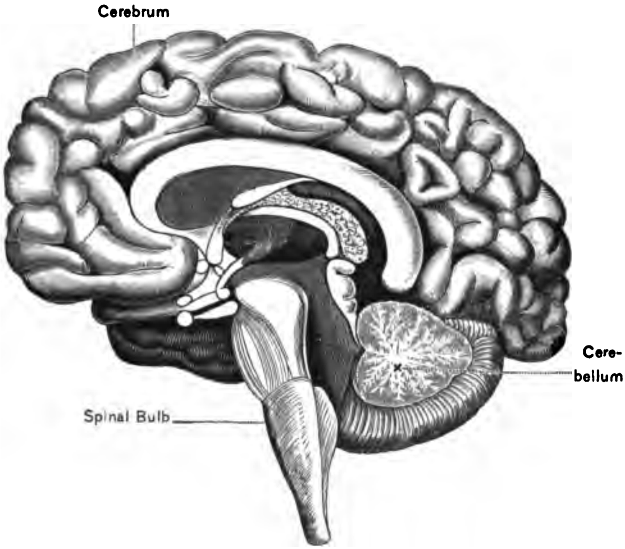



Fig. 87. — Vertical section of brain

The cerebellum is the center for regulating the actions of the skeletal muscles. When we walk or run, or even stand still, a number of muscles must act, and act in concert. The nerve impulses originate in the cerebrum, but the cerebellum is the center for harmonizing the action of these various muscles, or *coördinating* them.

In throwing a stone, a number of muscles are used. Each one of these must shorten in the right way and at the right time or the throw will not be accurate. Each muscle shortens under the influence of a nerve impulse started by the brain and brought by a motor

nerve. If any muscle shortens an instant too soon, or a little too strongly, the stone goes to one side. In a tune on a piano we know that the right keys must be struck, that each must be struck at the right time, with the proper degree of force, and held for the right length of time, or we have discord instead of harmony.

**Cause of Temporary Loss of Muscular Power.** — It may have happened to you that after sitting long in one position you attempted to stand, but found that you could not do so. One leg failed to act at the bidding of your will. When the foot is "asleep" we get little sensation from it; we hardly know whether it is touching the floor or not. Pressing on it with the other foot causes no pain.

If we try to stand when the foot is asleep, we are unable to do so. The brain starts the nerve currents, and they run along the nerve as far as the compressed part; here they stop. They cannot reach the muscles of the leg below. Hence the muscles do not shorten, and we do not rise, no matter how strongly we will to do so.

Why is it that the nerves and muscles thus sometimes lose their ability to perform their natural activities?

This has been explained by saying that, owing to external pressure, the nerve has temporarily lost its power of conducting nerve currents. But what besides the nerve has been compressed? What process in the limb has been interfered with by the pressure due to the position in which one has been sitting or lying? What is the temperature of the benumbed limb? On what are the nerves and muscles so dependent for the maintenance of their activity? (See also page 211, Nerve Impulses.)

**The Cerebrum.** — After passing intermediate parts of the brain on our way up from the medulla and cerebellum we come to the large, overhanging cerebral hemispheres,

the fore-brain. It is called the *cerebrum*. See in Fig. 87 its immense size as compared with other parts of the brain.

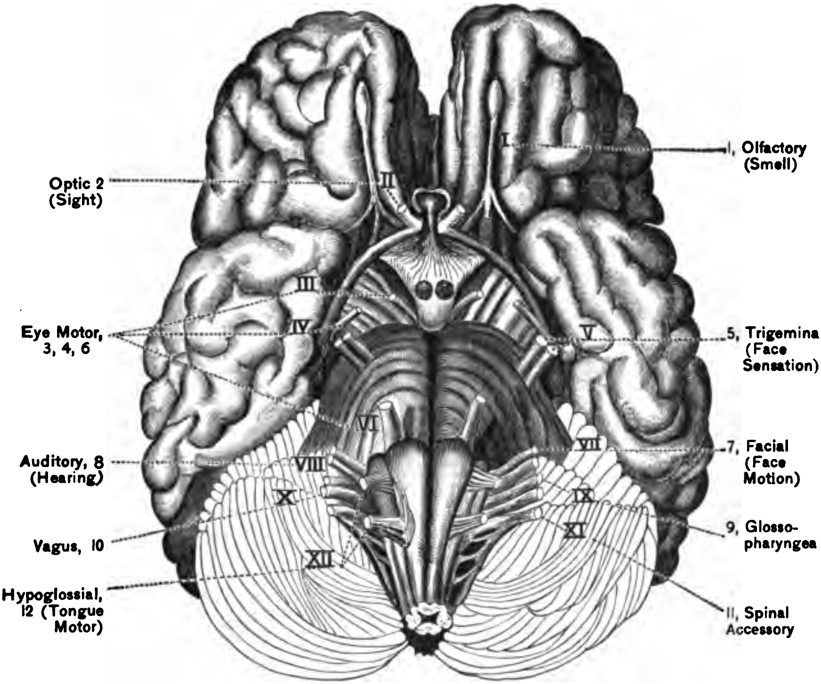



Fig. 88. — The base of the brain, showing the origin of the cranial nerves

The cerebrum consists of two lateral hemispheres, separated by a deep median groove. The surface of the cerebrum is in irregular ridges, the *convolutions*. The outside of the brain consists of gray matter, whereas the outside of the spinal cord is white. The inner part of the brain is white, and the two halves are connected by a broad band of white matter, which consists of many white fibers.

There are two readily distinguishable coats of the brain, the *dura mater*, a tough membrane, adhering more or less closely to the inside of the skull; and the *pia mater*, next to the brain, a much thinner

membrane, traversed by blood tubes, and dipping down into the grooves between the convolutions of the cerebrum.

**The Water Cushion of the Brain.** — Between the coats surrounding the brain and spinal cord there is a layer of liquid, comparable to that around the heart or lungs. When an undue amount of blood is sent to the brain, it is supposed that part of the cerebro-spinal fluid is pressed out into the spinal cavity, thus relieving the pressure in the brain cavity.

**Blood Supply of the Brain.** — Blood is supplied to the brain through four arteries: the right and left internal carotid arteries, and the right and left vertebral arteries. These arteries are so connected by cross-branches that if any three of them should be compressed, or the blood flow in them otherwise stopped, the fourth would still be able to give the brain blood enough for its work. When the brain is more active it receives a larger supply of blood. During sleep it is paler.

**Brain Convolutions and Intelligence.** — The brain of the rabbit has fewer convolutions than that of the cat, and is nearly smooth. In general, the lower animals have fewer convolutions, and the lower races of mankind have smoother brains than the higher races. As we know that intelligent action depends on the gray matter of the surface of the brain, we infer that to accommodate its increase in the brain-case it is thrown into folds.

**Gray and White Matter of the Brain.** — The gray matter of the convolutions of the adult human brain is about one-fifth of an inch thick, the larger part of the brain consisting of the white matter. Sections will show that there are several masses of gray matter in the brain deeper than the convolutions. These are the ganglia or nerve centers of the brain. The white fibers inside the brain connect

the gray matter of the convolutions and these ganglia with all parts of the body through the spinal cord. The gray matter is, physiologically, more active than the white, and in keeping with this is the fact that the capillary network is closer in the gray matter than in the white. This is true of the spinal cord as well as of the brain.

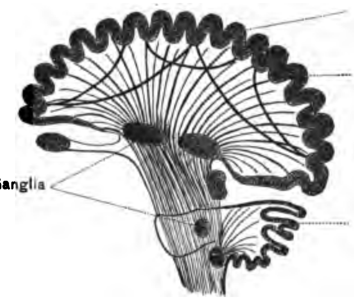


Fig. 89.—Diagram of the brain, showing the spinal cord, ganglia, and course of the fibers

The gray matter of the outside of the brain is the central organ of intelligent sensation and motion. The functions of *intelligence* depend upon the activities of the cells of the gray matter in the convolutions of the cerebrum. This has been learned from experiments on the lower animals, and from accidents and disease in the case of man. All sensation seems to be in the gray matter of the convolutions of the cerebrum, and yet it is itself insensible; it may be cut and cause no pain.

**Location of Brain Functions.** — Much has been learned as to the location of special functions in the brain. Many of the motor centers have been determined in the following manner: In some of the lower animals the brain has been exposed, and on stimulating certain portions with an electric current the movements that followed were noted.

A few years ago a young man was borne unconscious from a football field and lay in apparent stupor for several days. A number of physicians were called, but none of them could tell where

or what the injury was. Finally, the family called one of the most eminent brain specialists in the country, and after examining the patient and watching him for a few hours, this doctor said, "I may not be right, but, in my opinion, the only hope for this young man is an operation which will consist of opening the skull to examine the brain to see where there is pressure on it. Even this may not

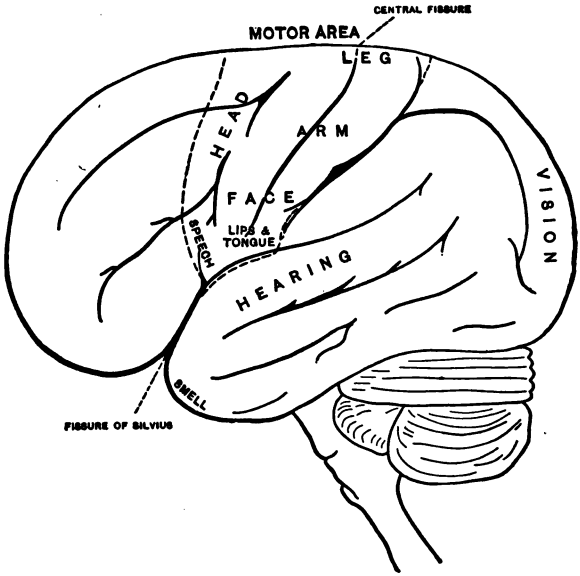



Fig. 90. — Location of brain functions

be successful, but I know of nothing else to do." The family consented, the operation was performed and was successful; the patient regained consciousness for the first time in many days. Amid the thanks and rejoicings of the family, the surgeon said, "I affirm, on my honor as a scientific man, that I could not have detected the injured area nor could I have performed the operation to restore this patient, were it not for experiments I have made upon animals." Of course, all experiments on animals should be *humanely* performed, without prolonging the operation or inflicting needless pain.

**Functions of the Fore-brain.** — The gray matter of the cerebrum has been mapped into areas which are shown in Fig. 90. The back of the cerebrum is concerned with vision, the lower small lobe with hearing, and on its inner surface are taste and smell. These are closely related. The middle is associated with voluntary muscular movements of different parts of the body. The front part, which we are not able to connect with any of the senses or with muscular movements, is associated with the power of thought. The center of speech is unlike the others mentioned, in that it does not exist on both sides of the brain. In right-handed persons it is located in the left hemisphere, close to the auditory area. In left-handed persons the speech area is said to be located on the right side. The determina-

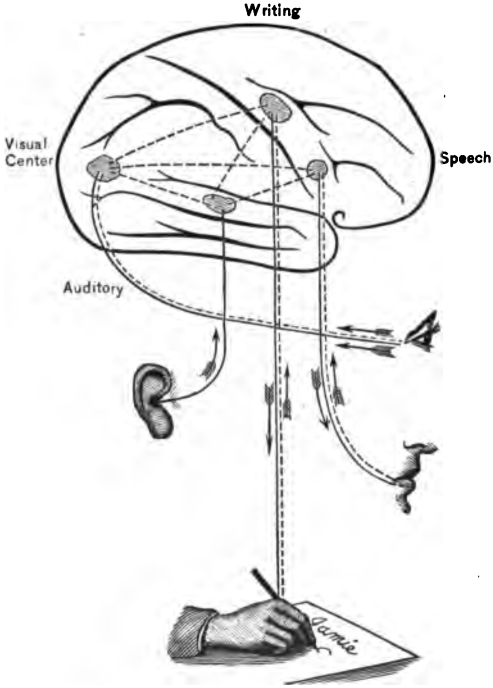



Fig. 91. — Connection of brain centers by association fibers (After *Landois and Stirling*.)
**The dotted lines from the hand, mouth, and eye represent afferent fibers from the skin, muscles, and joints of the hand, lips, orbit, etc.**

tion of the speech center is made when a child begins using its hands. The motor centers which move the hands are close to the centers that move the muscles of the face, lips, and tongue, and so the motions of these are added to movements of the hand to make sounds that the baby learns as words. Cases have been reported of children who suffered paralysis of the speech centers, in whom after a year the speech centers in the other hemisphere of the cerebrum were taught to talk as well as those first educated.

**Location of Centers of Sensation.** — It is not so easy to locate the centers of sensation as those for motion. For we can see the resulting motion, but a sensation can only be felt by the individual in whom it occurs. Still, some of the sensation centers have been located, and it is likely that in time we shall know much more on this subject. Fig. 91 shows some of these centers.

**The Relative Nature of Sensations.** — If one hand be held in a basin of hot water and the other in a basin of cold water, and then the two be suddenly plunged into a third basin containing tepid water, a sensation of cold will be received from the hand that was in the hot water, while the hand from the cold water will feel heat. Sensations depend on comparison and contrast. After listening to low sounds, a sudden loud noise is painful; and after hearing loud noises, it is difficult to detect slight sounds. We hardly notice the gradual fading of the light at sunset. And the nose does not usually detect the slow fouling of the air in a room; but let one come in from the fresh outside air, and the contrast is striking.

**Other Illustrations.** — A constant current of electricity usually causes a muscular contraction at the time the current enters the muscle and at the time when the current is stopped, that is, at the "making" and the "breaking" of the current; but the muscle ordinarily remains inactive while the current is passing. The interrupted current, or induction current, is therefore commonly employed as a stimulus in physiological experiment. A sud-

den stimulus seems to be better for producing the nerve impulse necessary to rouse a sensation in ordinary circumstances. Pressure may be applied so gradually that we fail to notice it. The art of the pickpocket depends largely on this fact. The act is so gradual that no sudden change is noted. In smelling it is often necessary to sniff; the sudden rush of particles of air bearing the odorous particles against the surface bearing the nerve endings seems to be necessary.

**Ignoring Nerve Currents.** — The brain undoubtedly is constantly receiving and sending nerve currents to which we pay no heed, or at least of which we are not conscious. For instance, our clothing is touching nearly the whole of the surface of our bodies, and, plainly, the surfaces thus touched are affected. Undoubtedly currents go to the brain, but as they are of no significance in ordinary circumstances, we learn to disregard them. If a savage were suddenly clothed as fully as we are, he would for a long time be continually conscious of the fact. We are not conscious of expending energy in standing until we begin to be weary; but the fact that a blow on the head causes one to fall reveals the fact that the brain is constantly sending messages to the muscles to make them act. The shock of the blow has stopped the sending forth of these messages, and so the body is no longer supported. None of the muscles that support the body have been injured or even touched.

**Dreams.** — During sleep the fore-brain ignores all afferent nerve impulses. Though they continue to come to the brain, we are not conscious of them except in semi-conscious intervals of sleep. These fragmentary remembrances of such thoughts are then called *dreams*. Dreams are often traceable to nerve impulses brought from the digestive tract, from the respiratory organs, from the skin (heat and cold and pressure), from sound, from any internal organ, according to the condition of the blood pressure, etc. It seems to be well settled that dreams seeming to cover long periods of time really take place in a very short space of time, just as sometimes during waking hours thoughts fly through the mind in countless numbers and with incredible swiftness.

**Summary.** — It is desirable to get a good mental picture of the work of the components of the nervous system. It will be recalled from their description, page 208, that the cell bodies of the

neurons send out the axons or nerve fibers. Now every nerve fiber goes to some cell in the body to which it transmits its impulses. These cells may be gland cells, muscle cells, or nerve cells. The result produced by the impulse that comes to the cells does not depend on the kind of stimulus, nor on the impulse, but on the kind of cells that *receive* the impulse. Whenever an impulse comes to a muscle cell it contracts; when one comes to a gland cell it secretes. Nerve cells in the fore-brain give us sense impressions according to the source of the nerve fibers that bring the impulses. Thus the brain cells that receive the impulses over the optic nerves give us sensations of light, whether the impulses were started by the normal stimulus light, or whether a blow on the head caused us to "see stars." Pressing the eyeball, disease, and other injury of the optic nerve likewise give faint light flashes. The same is true of the sensations arising from the impulses started in the other organs of special sense.

From the above it becomes evident (1) that nerve fibers are probably all alike, and merely conduct impulses; (2) that the impulses are only signals started by nerve stimuli, transmitted over the nerve fibers in some unknown way; (3) that the normal effect of all impulses is to produce either action or sensation. And our sensations are the foundation of our understanding, our intelligence.

## Hygiene of the Nervous System

**Its Importance.** — As there is no function of the bodily organs and no activity of the mind which can take place without the stimulus and direction of many nerves, *the hygiene of the nervous system becomes the most important of all health problems.* One frequently hears the expression, "O yes, I am quite well; only I am nervous." The speaker in such cases surely cannot realize how any slight disturbance of the nervous system may affect the health, since all vital processes and all mental powers depend upon a vigorous condition of the nervous system.

Perhaps no other period of history and no other country has made so many demands upon the nervous energy of its

people as does America at the present day. Rapid communication between communities and individuals, the multiplication of machinery and inventions of all kinds, the crowding of people into cities where life is busiest and most complex, all tend to overstrain the nerves and weaken the vitality. It is significant that we are called by Europeans "the nervous Americans." More significant and more alarming is the increase of all minor nerve disorders and of insanity.

**Moderation and Self-control.** — More and more should the necessity of these two virtues be instilled into the young and practiced by the adult. Seldom, now, does a physician prescribe a nerve stimulant; nerve *sedatives* are much more in order. To minimize the effect of nerve excitations, to know what to leave out of the many popular forms of activity and amusement, to "study to be quiet," should be the aim of every one who cares for his own health and the welfare of others.

Work — even hard work — is not injurious. Exercise of the nerves is as healthful as any form of exercise; indeed, the neurons which are unused are liable to atrophy and disease. Work should be regular in time and amount and should be alternated with rest and proper recreation. Above all, the habit of self-control should be early acquired and constantly practiced. Gusts of passion, anger, and feelings of revenge are known to have a harmful effect on the nerves as well as the character, and we should have sufficient self-control not to indulge in them.

**Habit and Efficiency.** — Habit is a powerful factor in the brain life of any person. We should train our nervous system to be more efficient instead of neglecting or injuring it. To do this, all necessary activities that can be,

should be made automatic as early as possible. Inaccurate or careless habits consume more time instead of saving it. Proper habits save the brain much conscious effort, leaving room for higher mental activity. It would be well to study our ways of doing things while we are young, as then it is easy to form useful habits.

**Brain Work and Brain Rest.** — Sleep is not merely rest for the body; it should be complete rest for the brain. In so far as there are dreams, it would seem to indicate a partial activity; that is, incomplete rest. The brain worker especially needs plenty of sleep; excellent authorities say at least eight or nine hours. The brain, like the muscles, needs exercise, and it also needs regular periods of rest.

Intense brain work, without sufficient sleep, is likely to lead to sleeplessness, as when one has some subject of special study in hand and either will not or cannot throw it off. Perhaps inventors are as prone to this sort of trouble as any one class of men. Keeping the blood continually in the brain, or in any organ, is likely to lead to a permanent congestion or inflammation that may cause serious, if not fatal, results.

It is stated that brain workers need more sleep than those who work chiefly with the muscles. Fatigue of the voluntary muscles is much more a matter of nervous than of muscular origin. When one is completely "tired out," as he would say, if his mind can be aroused, as by some excitement, he will be found able to expend a good deal more muscular energy. So, too, many persons of slight muscular build, but of great "will power," are able to do more work with the muscles than others with larger muscles and less will. During fatigue the cell bodies are found to decrease in size, but there is no discernible change in the axons as a result of fatigue.

**The Usefulness of Resting.** — We have, in youth, such a boundless store of energy that we do not sufficiently

consider these matters. But if one wishes to follow the intellectual life long and successfully, he must learn to economize energy, and to direct his forces into useful channels. And one important part of this knowledge is learning how to rest. It is an art that very few have well learned.

Even when one is supposed to be resting, he seldom relaxes all his muscles until sleep overtakes him. Careful observation of one's self and others will often show the body held taut, braced by the foot on " tip-toes " rather than by planting it squarely on the floor. If we could learn to throw ourselves down, as an animal does, with all rigidity gone, a few minutes' rest would be worth an hour's half-rest.

**How to Rest the Brain.** — The student should acquire the power and cultivate the habit of having, so far as possible, regular hours for work, and of completely throwing aside his work and worry at stated times. In seeking recreation it is well to choose that which will give complete rest from the daily work. For this reason chess may be no real recreation for the student, while a game of tennis, boxing, or other competitive exercise is likely to accomplish this object. A walk may put the muscles into play, but if the mind is still intent upon the line of work maintained throughout the day, the exercise may prove of little benefit. He may return more tired than when he set out. He adds a tired body to a weary mind.

## Brain and Nerve Ailments

**Fainting.** — If the supply of blood to the brain is shut off, unconsciousness quickly follows. In the ordinary faint the blood supply has been reduced, owing to diminution of the blood pressure or the heart's force. It may be due to inhibition of the heart from some emotion, or

bad odor, as in a close room; severe pain may be the cause; a blow over the pit of the stomach may stop the heart by reflex action. For remedies see page 337.

**Headache.** — This is perhaps the most common form of suffering from nerve tension or disorder. It may be caused by indigestion, by congestion of blood in the head, or by poisonous products which irritate the nerves. Pain in the head — like all pain — should be a warning and cause us to examine our ways of living that we may set right whatever is wrong. But resorting to bromides and opiates for the relief of headache is a dangerous practice, as these powerful drugs deaden and weaken the nerves. The use of the advertised "headache powders" is also a dangerous refuge, for these weaken the heart as well as deaden the nerves, and it is said that their consumption has made heart disease more prevalent.

Pain in the forehead ordinarily indicates digestive disorders or constipation. That in the back of the lower part of the head may result from overtaxing the nervous system; it may also indicate affected eyes. Affections of the organs of special sense may make themselves felt in the temporal region — over the ears. The top of the head, when aching, warns of anemia and trouble in the lower abdominal region. This does not refer to headaches of short duration, but to those that persist.

**Neuralgia.** — This is a common and very painful affection of the nerves. It may be induced by worry, overwork, or some nervous shock. It usually affects the facial nerves most seriously, though it may be felt in any part of the body. It is characterized by sharp twinges of pain, and sometimes by dull pain, which is felt most at night. Rest, freedom from worry, and attention to the general health are the best means of recovery.

**Neuritis.** — Inflammation of the nerve sheath, and neurasthenia, "nerve weakness," are two other common and serious forms of nervous derangement. One variety of neuritis is called "shingles," in which painful skin eruptions appear that resemble the rash of skin diseases. Another kind of neuritis is sciatica, an affection of the sciatic nerve.

**Tetanus.** — The convulsions which often place this with muscular diseases are really due to the constant and continued stimulus of the nerves by the poison of the tetanus germs. From the repeated stimuli the muscles are kept in a violently contracted state. Finally, death results from exhaustion. If taken in early stages, relief, and sometimes cure, is accomplished by injection of a serum prepared from the blood of horses that have been inoculated with tetanus germs.

**Apoplexy.** — Apoplexy is caused by rupture of a blood tube and the formation of a clot that presses on the brain.

**Meningitis.** — Meningitis is an inflammation of the membranes immediately surrounding the brain or spinal cord or both.

**Infantile Paralysis, "Poliomyelitis."** — This disease has increased alarmingly within the last few years. It afflicts mainly children from two to five years of age, but a few cases have been known among adults. It is supposed to be of germ origin. The affected parts are the spinal nerves and the fluid around the spinal cord. There is intense pain, followed by partial or complete paralysis, sometimes causing death in a few days. From experiments on animals, it is thought that the infection is carried from one to another, but some physicians believe that the disease is carried by stable flies — another reason for making war on flies.

### QUESTIONS FOR REVIEW

1. How can the will make distant muscles contract?
2. What are the parts of a neuron?
3. Why are nerve fibers white?
4. What is meant by motor path?
5. Locate a sensory path.
6. Why are sensory nerves (axons) called afferent? What are the motor axons also called?
7. What is meant by sensation?
8. What is the first step in nerve action?
9. After naming some nerve stimuli tell whether you think they are part of the nerve action. Why?
10. Of the things in nerve action — which is carried; which is felt; what is the beginning?
11. What are the main parts of the nervous system?
12. How many cranial nerves are there? How many spinal nerves?
13. What two kinds of nerves in *each* spinal nerve?
14. Locate the sympathetic nervous system.
15. What vital processes are regulated by the sympathetic nervous system and the spinal cord?
16. Of the cranial nerves, name those that supply only organs of special sense.
17. How do spinal nerves enter and leave the cord?
18. Which way do impulses travel on each of them?
19. How are nerve trunks formed as illustrated by the sciatic? Where do the individual fibers end?
20. What are the vital processes? How are they regulated?
21. Explain some special uses of reflex action.
22. What is the spinal bulb?
23. How does the position of the gray matter in spinal cord and cerebellum compare?
24. What is the main function of the cerebellum thought to be?
25. What are some characteristics of the cerebrum? Name its coats.
26. What is meant by the " water cushion " of the brain? What is its use?

27. What blood vessels besides the carotids supply the brain?

28. What advantage in having four arteries to the brain? (See "blood supply.")

29. Why is the surface of the brain folded or convoluted?

30. What is the relative position of gray and white matter in the cerebrum as compared with other parts of the central nervous system?

31. How were the locations of brain functions determined?

32. What part of the brain originates voluntary motions? What part coördinates or regulates them?

33. How does the speech center differ from others in location?

34. How have children learned to speak again after losing that power through some illness?

35. What relation is there between the use of the hands and the location of the speech center?

36. Under what conditions is work not injurious?

37. How may we become more efficient in general? How does reflex action assist efficiency?

38. What are the best ways (four) of resting the brain?

39. What has interested you most in this chapter?

## CHAPTER XIII

### SENSATION AND ORGANS OF SPECIAL SENSE

**Dependence of Mental Growth on the "Senses."** — The brain may be called the physical basis or seat of the mind, — of "perceiving, remembering, thinking, willing, and desiring," — while the mind may be called the sum of the faculties that develop in the brain. But how much mind should we have if we did not receive messages from the outer world? We are continually getting knowledge of the outer world and of the condition of our own bodies through the afferent nerves. These incoming currents pass along myriads of nerve fibers. But the nerve fibers are all essentially alike.

Without these afferent impulses there would be no mental development. Professor Foster of England tells of a man who was blind in one eye, deaf, and suffering from general anesthesia. Whenever the sound eye was closed he went to sleep. In our own country, Laura Bridgman, born in 1829, was educated to write, read, and communicate with others though she had only one other special sense besides touch, partially developed.[1]

NOTE. — If one could imagine a creature born with no afferent nerves, or even a child devoid of all the (five) senses, so-called, one may be sure no mind would develop. There must be at least one avenue open to the brain, in the beginning.

[1] Not touch alone, as some authors have asserted. Read the story of her life; also the *Life of Helen Keller*, who had two senses.

**General and Special Sensations.** — We may distinguish special or more definite sensations induced by impulses from the organs of special sense, and general sensations such as pain, hunger, thirst, nausea, satiety, faintness, fatigue, and muscular sense, due to conditions of the organs of the body. The latter are also called "common sensations." Martin designates them as "sensations which we do not mentally attribute to the properties of external objects, but to the conditions of our own bodies."

**General Sensations.** — Nerve endings in different parts of the body may be affected by the blood and the lymph, and give us sensations of comfort, discomfort, restlessness, fatigue, faintness, etc. These are called *general sensations*. They are probably due to the condition of the blood, or to the condition of nutrition of the various parts of the body. Thus after muscular exercise the muscles are acid in their reaction, while they are alkaline after resting; during exercise carbon dioxid accumulates in them to a certain extent. Hunger and thirst come on after abstinence from food and drink, or after work exhausting the tissues. The presence of the various waste products, or the condition of the cells as the result of their activity, acting through the nerve endings in the tissues, keeps the nerve centers informed as to the condition of the parts of the body. If these conditions are extreme, we may have definable sensations, but ordinarily the sensations are of an undefinable sort which we designate as "general or common sensations."

**Hunger and Thirst.** — The cause of these sensations in a healthy body is plainly the need of food and water throughout the system generally. The sensation of thirst manifests itself in the throat, and the longing may be temporarily relieved by merely moistening the throat. So

hunger may, for the time, be appeased by filling the stomach with indigestible material. But the sensation soon returns.

**Pain a General Sense.** — In the real "special senses" we refer the sensation to some external object, whereas general sensations are subjective, referred to our bodies. Ordinarily we do not localize the common sensations, and a further indication of the relationship of pain and general sensation is in the lack of complete localization of pain. Slight pain, especially in the skin, may be closely located, but pain in internal organs tends to become indefinite and diffuse. So we may class both the muscular sense and pain with the "general" rather than with the special sensations.

**The Muscular Sense.** — Peculiar nerve endings have been found in the tendons; the joints are believed to have an especially rich nerve supply. It is not necessary that we actively use the muscles to have sensations of this kind. In passive movements, as the raising of the arm by another person, we have a "sense of position" of the parts, a considerable share of which is probably due to the tension of the skin and changes in the joints. There is, of course, some tension of the muscle, even in this passive movement, that might affect nerve endings in it. The muscular sense is closely related to general sensibility, if not a modified form of it. It is difficult to realize the importance of this sense in our daily experience. We probably underestimate it, and attribute to sight too much of our knowledge of the external world. The fundamental facts concerning the objects about us are not obtained through sight alone, but are the outgrowth of tactile and muscular perceptions.

**The Organs for Special Stimuli.** — Although there is some objection to the current expression "organs of special

sense," it is retained with the understanding that it means organs for receiving special stimuli external to the body.

All our knowledge of the external world comes through the organs of special sense, the ears and eyes, the nose and tongue, and the skin. Some of these organs are excited or affected by more than one kind of stimulus, *e.g.*, the tongue by taste and touch; the skin by touch (pressure), heat, cold, and pain. So instead of the familiar "five senses," we really have eight, as we shall see in the following pages.

## Feeling

Let one person rest the hand flat on the table, palm upward, and close the eyes. An object placed on the palm, by another person, may give rise to various sensations, so that it may be described as rough or smooth, light or heavy, hot or cold, wet or dry. If the object is very heavy or very hot, it may cause pain. If now the thumb and fingers are raised and applied to the object, more definite information will be gained as to its shape, size, surface. Now raise the object in the hand, and further appreciation will be gained as to its weight. If it has sharp points it will cause pain. The sensations from the skin may be called cutaneous sensations. They include: (1) the pressure sense, or touch proper, (2) the temperature sense (heat and cold), and (3) the pain sense.

**Papillæ and Nerve Endings.** — We need now to recall the conical elevations in the dermis that are called *papillæ*. They contain the oval touch corpuscles in which the nerves end, and are also called *end-organs*. (Fig. 92.) Pressure on the skin affects these nerve endings, and starts impulses that pass along the sensory fibers to some nerve center, probably in the spinal cord, spinal bulb, or brain. Nerve

endings in the skin seem necessary; for if a nerve fiber be touched, not at the end, but somewhere along its course, we get, not a sensation of touch, but a sensation of pain. Except in the mouth and nose, we get little, if any, sense of touch from any organ but the skin. The lining of the digestive tube and the internal organs generally are devoid of this sense.

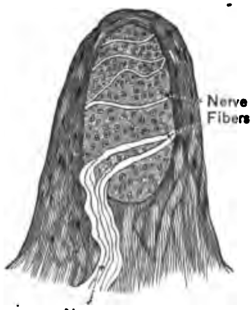



Fig. 92. — Papilla of skin with touch corpuscle. The oval body is the corpuscle

**The Sense of Touch.** — Of the special senses the most general is that of touch. Seeing and hearing, tasting and smelling, belong to very limited parts of the outside of the body, but we have the power of feeling all over the surface of the body. The sense of touch is strictly a *pressure sense.* If we test the skin to find what regions are able to detect the least pressure, it is found that the forehead is most sensitive, and nearly equally so are the temples, back of the hand, and forearm.

**Touch the Most General of the Special Senses.** — Not only is the sense of touch the most general in being distributed over the whole of the body, but it is the most widely distributed sense throughout the animal kingdom. As we descend the animal scale we find many of the lower animals lacking some of the senses that we possess. In many of the simpler forms of animal life there is no evidence of a sense of hearing, and it is extremely likely that if they have taste and smell, these senses are in a very rudimentary state of development. But in all these forms it is believed that "feeling" exists. Contact of their exterior with foreign objects is so often immediately followed

by action that little doubt remains about their having the sense of touch. Even the ameba may have, in a rudimentary state, the power to distinguish light, to taste, and to hear. Still we have little or no evidence on these points, while we are pretty sure that it feels.

The ability to detect differences of pressure is tested by finding what is the least addition to a weight required to make it seem heavier. For instance, if a weight of 11 grains is just perceptibly heavier than one of 10 grains, it does not follow that 1 grain added to a weight of 100 grains will give any palpable increase. To 100 grains must be added 10 grains before additional pressure is felt; that is, whatever the weight, there must be the *same ratio* of increase to increase the sensation.

**Accuracy in locating Touch Sensations.** — The accuracy varies, and is ordinarily keenest where the nerves are most numerous. Where the sense of locality seems to be improved by cultivation, this appears to be due to keener discrimination in the brain cells, and not to changes in the nerves or nerve endings. This is indicated in the fact that if the fingers of one hand become more discriminating by practice, it will be found that the fingers of the other hand, without special training, are also improved. If a fly alights on your hand, you do not brush your face to remove it, but you do brush your hand. You can tell where you are touched, as there are brain areas connected with skin areas.

**Reference of Sensation to the Region of Nerve Endings.** — If the "funny bone," or "crazy bone," be hit, *i.e.*, if the ulnar nerve be bruised against the bone, sharp pain may be felt in the wrist and hand, and soreness of these parts may be felt for days, though they are not in the

least injured, but only the nerve at the elbow. The currents along this nerve rouse sensations that we have learned to localize at the endings of the nerve fibers.

**The Temperature Sense.** — Many cases are on record in which, from accident or disease, the pressure sense was lost and the temperature sense retained, or *vice versa.* Such facts have led to the belief that the temperature sense is distinct from that of touch, and has its own nerve fibers and nerve endings.

In some diseases of the spinal cord the skin may be affected by warmth, but not by cold. The sensations of cold and pressure seem to be usually lost or retained together, while those of warmth and pain have a similar connection. But more accurate results are obtained by touching the skin with a blunt metal pencil, warmed or cooled.

**Warm Spots and Cold Spots.** — If this be applied at regular close intervals, it is found that some places feel the warm point, while others feel the cold. In this way the skin has been mapped out into " warm spots " (warmth-perceiving spots) and " cold spots " (cold-perceiving spots). Still other areas seem not sensitive to temperature.

**Two Sets of Nerve Fibers for Distinguishing Heat and Cold.** — Since heat and cold are only differences in the degree of heat, we would expect both of these kinds of impressions to be received through one set of nerves. There seems, however, to be good evidence of two sets of nerve fibers, one for heat and the other for cold. In the common experience of the foot " going to sleep " by pressure on the sciatic nerve, or the arm from compression of the brachial nerve, the skin may be found, at a certain stage, to be only slightly sensitive to warmth, while distinctly sensitive to cold.

**Pain Sense.** — In reference to pain in the skin, it is held that the skin, too, has its nerves of general sensibility, and that these are distinct from those of touch and temperature sense. That when they are unduly stimulated they give rise to painful sensations. It is to be noted that the internal organs are ordinarily devoid of feeling, and that the skin is especially sensitive. The skin senses stand guard at the outposts, so to speak, of the body's camp, and give warning of approaching danger. No enemy may enter without being discovered by these keen sentinels, and the alarm is given. If it is not heeded, great harm may follow. However, it is a comfort to know that the more severe wounds do not cause pain in proportion to their extent.

## TASTING

**Uses of the Sense of Taste.** — The sense of taste helps us in judging of the fitness of anything that presents itself as a candidate for election as food. By reflex action the taste of agreeable substances aids in digestion by stimulating the glands, especially the salivary glands. The sense of taste is of interest immediately after studying touch, because the tongue, the special organ of taste, is also a very delicate tactile organ. Every one has noticed that the minutest hard particles of bone or eggshell can be detected and singled out in a mouthful of food.

**What we Taste.** — Substances must be dissolved before they can be tasted. If the tongue be wiped dry, and a few grains of salt or sugar be placed on it, the taste will not be perceived for a little time. Insoluble substances give no taste.

**Flavors.** — What we call flavors do not affect us through the sense of taste but through smell. If the nose be held shut, and we are careful not to breathe through it, a piece of

onion placed on the tongue does not produce what we usually call the taste of the onion. We may thus get rid of the disagreeable part of taking certain medicines.

**How we Taste.** — Although we ordinarily speak of an article of food as " palatable," or " unpalatable," the sense of taste in the palate is only feebly developed. The tip of


Fig. 93. — Diagram of tongue, showing nerves and papillæ

the tongue seems to be most sensitive to sweets and salines, the back part to bitters, and the sides to acids.

**The Papillæ.** — The surface of the tongue is covered with papillæ. These are of three kinds. Most numerous are the *filiform papillæ*, slender, cylindrical projections. Like the papillæ of the skin, they seem to be organs of touch. Scattered among the filiform papillæ are small, bright red spots which, on examination, are found to be shaped somewhat like a mushroom, the *fungiform papillæ*. Near the base of the tongue are about a dozen larger papillæ, arranged like a letter V with its apex toward the base of the tongue. These are the *circumvallate papillæ*, each having around it a deep circular furrow. On the sides of this furrow are small oval bodies, called " taste buds," connected with the ends of the nerves of taste.

**Conditions Affecting Taste.** — It is said that the temperature of about 40° F. is most favorable for tasting, and after rinsing the mouth with very hot or very cold water, such bitter substances as quinine will have only a trace of their usual taste. Every one knows how insipidly sweet and strong-flavored melted ice cream is, and those who

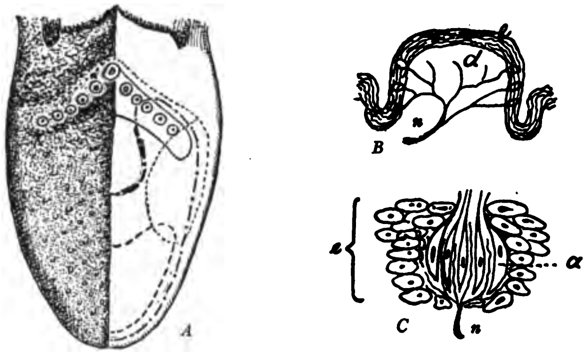



Fig. 94. — Sense organs of taste

*A*, map of upper surface of tongue, showing on the left the different kinds of papillas, and on the right the areas of taste (after Hall). Area sensitive to bitter (——); to acid (. . . . . .); to salt (—.—.—.—); to sweet (— — — — — —). *B*, section through a papilla; *n*, small nerve connecting with taste buds at *d*; *e*, epithelium. *C*, single taste bud magnified; *n*, nerve, the fibers of which terminate between the spindle-shaped cells *a*; *e*, epithelial cells

make it know that they must put in it much more sugar and flavoring than suits the taste at ordinary temperature.

It is said that raspberries are just as sour as currants, but because of a mucilage-like substance present in the berries, we do not notice the acid taste. As previously stated, only soluble foods give taste.

## Smelling

**Uses.** — "The sense of odor gives us information as to the quality of food and drink, and more especially as to the quality of the air we breathe. Hence we find

the organ placed at the opening of the respiratory passages, and in close proximity to the organs devoted to taste. Taste is at the gateway of the alimentary canal, just as smell is the sentinel of the respiratory tract; and just as taste, when combined with smell to give the sensation we call flavor, influences the digestive process, and is influenced by it, so smell influences the respiratory process. The presence of odors influences both the amplitude and the number of the respiratory movements. Thus the smell of wintergreen notably increases the respiratory work, next comes ylang-ylang, and last rosemary. The breathing of a fine odor is therefore not only a pleasure, but it increases the amplitude of the respiratory movements. Just as taste and flavor influence nutrition by affecting the digestive process, and as the sight of agreeable or beautiful objects, and the hearing of melodious and harmonious sounds react on the body and help physiological well-being, so the odors of the country, or even those of the perfumer, play a beneficent *rôle* in the economy of life." — *M'Kendrick and Snodgrass.*

**Why we Sniff.** — In quiet breathing the air passes along the lower air passages just above the hard palate. The true olfactory passages are higher, but still in communication with this lower passage. When we wish to test the quality of the air, we sniff, that is, make a sudden inspiration by jerking the diaphragm down, and air from the outside then rushes into these upper nasal passages, over the walls of which the nerves of smell, the olfactory nerves, are spread in the mucous membrane. The sudden rush of air against this membrane seems to aid greatly in detecting the odor. The nerves have peculiar endings, in cells and hairs, and it is not known just how the sub-

stances produce their effect. The substances must be in a very finely divided state, probably gaseous. The mucous membrane is supplied with mucus, and the odorous substance, probably, is first dissolved in the mucus. In inflammation, owing to their narrowness, the passages, especially the upper, are often closed by contact of the opposite sides. Substances like ammonia have no odor, but

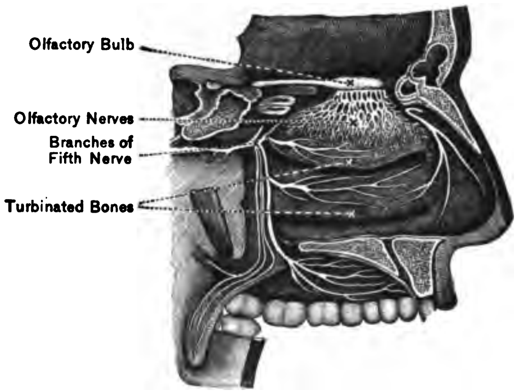



Fig. 95. — Nerves of the outer wall of the nasal cavity

excite the tactile nerves. They are often spoken of as having a "pungent" odor, but are simply irritants. Carbon dioxide may be detected by a prickling sensation in the nose, though it is called odorless.

**Flavors.** — That which we ordinarily call flavor is so made up of the two sensations that it is difficult to tell what part each plays in the effect upon us. Quite pungent and strong-flavored substances taste very different and are hardly recognizable if the nostrils are closed.[1] This is true of such

[1] Students might test this at home, or in a spare hour. See Exercises at the end of this chapter for directions.

flavors as vanilla and lemon, while the flavor of meats and of many fruits is not tasted at all; it is smelled. For this reason coffee tastes insipid when the nose is "stopped-up" by catarrh or a cold.

**Sense of Smell in Animals.** — In animals that have a keen sense of smell, the olfactory membrane in the nose is much folded for larger surface exposure to the air. (See Fig. 95.) If this membrane from a bloodhound's nose were stretched out flat, it would be several square feet in extent.

It is not the odor of the feet, as is commonly supposed, by which these animals trace their victims, or a dog his master, but by immeasurably small particles dropped along the path of flight. These particles have the personal odor by which the hound detects the right individual.

**Limitation of the Sense of Smell.** — We are much more sensitive to some odors than to others. Professor Howell states that vanilla may be perceived when diluted ten million times, *i.e.*, 1 part vanilla in 10,000,000 parts of air; musk, 1 in 8,000,000 parts; camphor, 1 in 400,000 parts. The sense of smell is easily fatigued and is then not so good a guardian of the air we breathe. We do not notice the bad air in a room until we return to the room after an interval of fresh air.

## Seeing

**Uses.** — In the fable of the blind man carrying the lame man whose eyes were good, we have an illustration of the dependence of the various organs on each other. We have learned how all our knowledge, both of the condition of our bodies and of the external world, comes through the nervous system. Through the senses that we have already studied, we learn almost nothing of

the external world except from actual contact. But sight reveals objects at a distance. Without the eye the body is comparatively helpless. The lame man that the body carries is a slight burden in comparison with the assistance which he renders. We can well afford to carry with us all the time two of these lame men to keep posted as to the objects beyond our reach. Of course touch is a great aid to our interpretation of what we see. But sight is evidently the main avenue of knowledge, the royal road along which come the messages which bring us the most news, which give us the keenest delight, which make us aware of most that we know of this world, and the only means of knowing that there are other worlds than the one we inhabit.

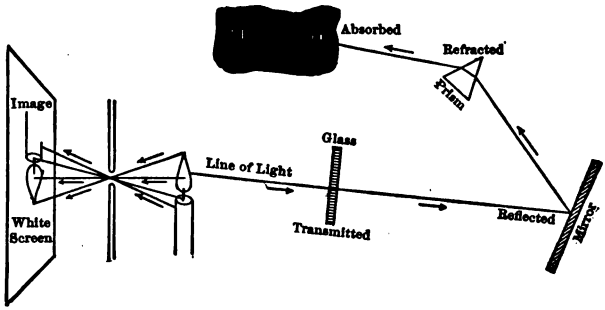
By this time we are familiar with the fact that the organs of special sense are parts of the body containing sensory cells for only one kind of stimulus. And these stimuli are the forces in nature which most affect the welfare of man and animals, *i.e.*, are either useful or harmful to them. There is no sense organ for perceiving electricity, probably because in nature it does not occur in sufficient quantity to be either beneficial or dangerous. We must, of course, except the lightning, of which animals have ample warning both through sight and hearing.

**Eyespots.** — In the lowest animals pigment spots, that is, colored granules, are deposited under the skin of the anterior end of the animal. The pigment absorbs the light, changing it into heat. Such an animal might be affected by light in several different ways: (*a*) the living substance through which the light passes before it is absorbed by the pigment is strongly illuminated; (*b*) the area of living matter under the pigment spot would be shaded and, per-

haps, be warmed. Such an animal could tell the direction of the strongest light, or the source of light, as we say.

In somewhat higher animals the cells in front of the pigment layer are connected with nerves and the skin over the pigment spot becomes thickened like a flattened bead of glass, *i.e.*, it becomes lens-shaped for intensifying the light.

NOTE. — Here we have the essentials of an eye: sensory cells which are stimulated by light and nerves to carry the impulse to a central or coördinating organ.




Properties of light

**Energy in the candle given out as light by oxidation; to the left it forms an image; to the right it is *transmitted*, then *reflected*, then *refracted*, then *absorbed*.**
**What are some properties of light?**

In our own eyes, as in the eyes of most higher animals, the large optic nerve spreads out its millions of sensory ends in the back and sides of the eyeball to receive the passing light coming through the front of the eye. The sensory ends of the optic nerve are so closely set in the back of the eye as to form a delicate layer.

**Field of Vision.** — While looking straight ahead, swing your hands from before your eyes around to each side until you can just see them indistinctly. What part of a circle is it? This is called the "field of vision."

**The Retina.** — The retina is a continuation and expansion of the optic nerve and forms an inner coat that lines all but the anterior part of the eye. It is a thin, translucent film, in appearance somewhat like the film that forms over the white of an egg when it is first dropped into hot water. The retina is the only part of the eye that is sensi-

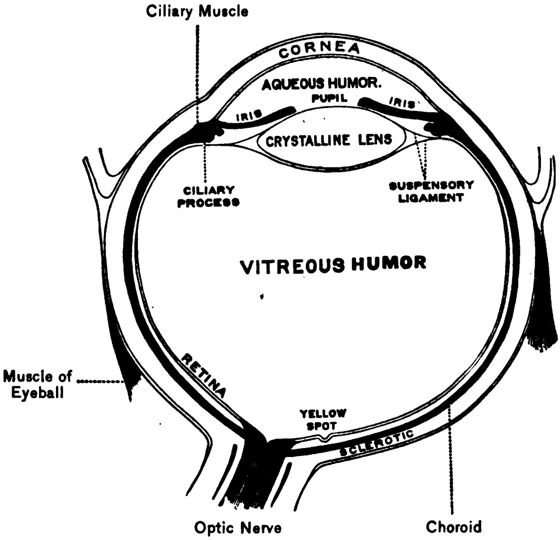



Fig. 96. — Horizontal section of right eye

tive to light, and on it the images must be formed to produce vision.

**Coats of the Eye.** — *The Sclerotic Coat.* The outside coat of the eyeball is the glistening white covering, so conspicuous when the eyes are rolled. It gets its name from its tough, hard appearance, hence, the *sclerotic* coat. (See Fig. 96.) The bulging front of the sclerotic is called the cornea. The large back chamber of the eye is filled with

a firm, jelly-like substance, as transparent as glass — the *vitreous humor*. Behind this is the retina, spread out in the back of the eyeball. Both the vitreous humor and the retina allow the light to pass through them. If, however, the light could go as far through as the inside of the sclerotic coat, it would be reflected and would dazzle the eye. To prevent this, there is a coat, the *choroid*, between the retina and the sclerotic coat. (See Fig. 96.)

*The Choroid.* — This coat is thinner than the sclerotic and of much more delicate structure. It is permeated by blood tubes, and has án inner lining of dark color to prevent the reflection of light in the eye, just as most optical instruments are painted black on the inside.

*The Iris.* — The front of the choroid coat under the cornea forms a sort of circular curtain — *the iris*. This is the part that gives the color to the eye, or if the pigment that gives the color is lacking, the blood gives the pink color seen in albinos. The iris has a hole in the center, *the pupil*, and circular muscle fibers that reduce the pupil when there is too much light for the eye. When the light is feeble, the pupil opens wider, by the outward pull of *radial* muscles.

*The Pupil.* — Most of the light that passes through the transparent cornea is stopped by the opaque iris. But in the center of the iris is a round hole through which light enters the interior of the eye. The *pupil* looks dark because it is the only opening into a dark room. (See Exercises.)

*Review of the Coats.* — Thus we see that the sclerotic coat is complete in front but perforated behind by the optic nerve; the choroid is perforated in front by the pupil and behind by the optic nerve. The retina of the eye alone

can give the brain sensations of light, but cannot give a distinct picture of an object, *i.e.*, an image.

**The Crystalline Lens.** — Just back of the iris is a double-convex lens, clear as crystal, and of about the consistency of a gumdrop. It is less convex on the front surface. It is called the *crystalline lens.* This focuses the lights (and shades) from an object so as to make a clear image or picture on the retina. (Fig. 98. See also Exercises at the end of the chapter.) It not only makes a clear image but a very small one compared with the size of the object.[1] The method of making a clear image or picture on the retina is called —

**Accommodation.** — Almost every one knows that in a good photo-camera the lens can be moved back and forth (focused) to get a sharp image on the sensitive film. Another way to accomplish the same result would be to have lenses of different thicknesses [2] for objects at different distances; a thick lens for near objects and a thin lens for distant objects. The crystalline lens of the eye accomplishes this by being flexible and elastic. It is quite thick and therefore suited for objects that are near. But it is normally flattened for far vision by the pressure of a transparent membrane, the *lens capsule*, which is drawn tightly over the front of the lens by thread-like ligaments. These ligaments (not muscles) attached all around the edge of the (lens) capsule,

[1] It is calculated that an 8-story building 1 mile away would make an image one one-hundredth ($\frac{1}{100}$) of an inch high on the retina; yet, in this tiny image we see (mentally) towers, windows, and projections of the building.

[2] The words *thick* and *thin*, in the description of lenses, are popular expressions, meaning more or less convex, *i.e.*, of greater and less curvature while of the same equatorial diameter. The lens of the human eye is $\frac{3}{16}$ of an inch thick, and $\frac{11}{32}$ of an inch in equatorial diameter.

pull outward and backward over the vitreous humor, holding the lens flattened against the latter. This is the resting condition of the lens, as no muscles (only ligaments) are in use. In looking at near objects muscle fibers (ciliary muscle, in Fig. 97) that run almost parallel with the ciliary ligaments contract and loosen the ligaments. The pressure of the lens being released, it thickens and thus is accommodated for near vision. But as this involves muscular action it is fatiguing, while far sight is resting to the eye.

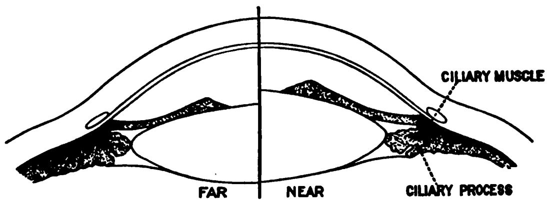



Fig. 97.—A diagram to illustrate accommodation

But the lens is not alone responsible for focusing an image on the retina; the curved surface of the cornea also helps. The space between the cornea in front and the lens and iris — which together form the back of this chamber of the eye — is filled with a transparent liquid —

**The Aqueous Humor.** — In looking at the entire eye it is not easy to realize that there is a space between the cornea and the iris. In this space is the clear, watery aqueous humor.

**General Statement of Seeing.** — The chief structure in the eye is the retina. Without this all else is useless. If light of sufficient strength falls on the retina, it stimulates elements in the end organs, rods, and cones, and the nerve impulses thus started pass along the fibers of the optic nerve to the brain, and we have the sensation of sight.

But in order to see anything distinctly, the light must fall on the retina in such a way as to form a distinct image of that object. If the lens be removed, or becomes opaque, as in "cataract," we fail to see distinctly, though we may discern light from darkness. The cornea, lens, and the aqueous and vitreous humors are the parts directly concerned in forming the images. Light from an object passes through the cornea, aqueous humor, lens, and vitreous humor, and the rays are so refracted as to form an inverted image.

**The Inverted Image.** — Nearly every one knows that the image in the eye is inverted as it is in a camera. And this has led to a discussion of why we do not see things upside down. Some writers try to explain "seeing right side up" as a slow process of education, or what is the same, that we learn to project things into space right side up, aided by the experience of the other senses. But the simplest explanation and that most generally accepted is that the optic nerve does not carry images to the brain, but merely impulses, which the brain interprets as sensations. In the brain there is no "upside down."

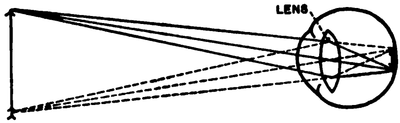


Fig. 98. — Light reflected from an object (the arrow) is focused by cornea and lens to form an image (inverted) on the retina.

**The Blind Spot in the Eye.** — The optic nerve, while capable of carrying nerve impulses that are interpreted in the brain as sensations of light, is not itself sensitive to light. Just where it enters the eyeball there are no sensitive endings, and this is called the *blind spot*. (See the Exercises for directions for finding the blind spot.)

**Area of Distinct Vision.** — On merely glancing at a page it would seem as if you could read the whole without moving the eyes. But if we look at only one letter near the middle of the page, and try to determine — without moving the eyes — how many letters can be identified on either side of the one chosen, we find that only a few letters can be clearly seen. This means that only a limited area or spot on the retina of each eye has distinct vision. It is called the central yellow spot, or *fovea centralis*. Here the end organs or *cones* of the optic nerve are more directly exposed to light. The fovea is about $\frac{1}{50}$ of an inch in diameter.

We can now understand why we always have to look straight at an object that we wish to see clearly, and also why we can see clearly, at one time, only a small portion of a large object that is near us. It is for this reason that we cannot read a page by looking steadily at the center; why we must follow the lines we are reading, word by word.

**Movements of the Eye.** — We see, then, that the eye must be constantly moving, in various directions. For this purpose there are six muscles moving each eyeball. The function of the four *recti* or straight muscles will be readily understood from Fig. 99 and the text. Of the two muscles that roll the eyeball, the *oblique muscles*, it is interesting to note that the upper oblique runs through a pulley, an unusual mechanical device for the human body. These six pairs of muscles move the eyes to right and left, up and down, and give rotary movements. Normally the two eyes move in the same direction at the same time, though

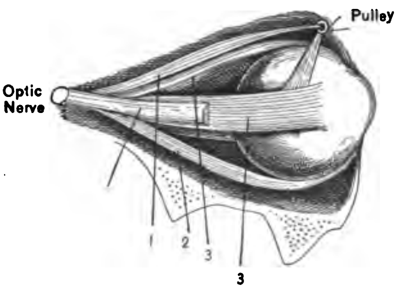


Fig. 99. — Muscles of right eye
1. Superior oblique muscle. 2. External rectus. 3. Internal rectus. 4. Superior rectus

in looking at near objects the two eyes both point inward, so that one appears cross-eyed, and in looking at an object that is moving away from one, the eyes are gradually diverging, though this is slight.

**Stereoscopic Vision.** — In looking at an object with one eye more is seen on the side nearer that eye, while the other eye sees more of the other side, considerable of the object being seen with both eyes. The effects produced on the two eyes are united, and so we see objects better as solids. This is what is termed stereoscopic or binocular vision.

A good illustration is seen in holding a book vertically with the back toward the eyes in such a way that both covers and the back can be seen. Now, if either eye is closed, the other eye sees only the back and one cover of the book.

**Color Sensations.** — The difference in colors is due to the differences in the rapidity of the vibrations of the waves of light, as in sound differences in the rapidity of the vibrations of the sound waves cause the various degrees of pitch. Many interesting experiments may be made with color sensation, most of which are difficult of explanation. (See Book-list.) It is found that some persons cannot distinguish certain colors. *Blindness* to red and green are most common. This is a matter of importance among railroad men and sailors where it is necessary to distinguish red and green signals.

**Duration of Impressions of Light.** — Most boys have amused themselves around a bonfire by whirling a stick with a glowing coal on its end. The continuous circle of light thus produced indicates that the impression of light remains for a time, in this case until the stick completes the circle, giving a continuous line of light. Or when riding in a carriage the spokes of the wheels blur together because the impression of each lingers till another has taken its place.

If we shut the eyes quickly, we may keep distinct the impression of the last positions, and so see them distinct from one another. Better still, shut the eyes while looking at the wheel, then open and shut them as quickly as possible.

## Hygiene of the Eyes

**Objectionable Light.** — In reading we wish light from the printed page. Hence we should avoid light entering the eye from any other source at this time. While reading, then, do not face a window, another light, a mirror, or a white wall, if it can be avoided. White walls are likely to injure the eyes. Choose a dark color for the covering of a reading table. Sewing against the background of a white apron has worked serious harm; a dark one should be worn.

Reading out of doors is likely to injure the eyes, especially when lying down. To try to read while lying in a hammock is bad in many ways. Too much light directly enters the eyes, and often too little falls upon the printed page.

**Strength of Light.** — Have light that is strong enough. Remember that the law of the intensity of light as affected by distance is that at twice the distance the light is only one fourth as strong. Reading just before sunset is not wise. One is often tempted to go on, not noticing the gradual diminution of light.

**Position in Reference to Light.** — Preferably have the light come from behind and above. Many authors say "from the left," or "over the left shoulder." In writing with the usual slant of the letters this may be desirable. Sitting under and a little forward of a hanging lamp will give the light equally to the two eyes and send no light directly into the face. In reading by daylight avoid cross-lights so far as possible.

**Evening Reading.** — In all ways endeavor to favor the eyes by doing the most difficult reading by daylight,

and saving the better print and the books that are easier to hold for work by artificial light. Writing is usually much more trying to the eyes than reading. By carefully planning his work the student may economize eyesight, and it is desirable that persons blessed with good eyes should be careful, as well as those who have a natural weakness in the eyes. It often results that those inheriting weak organs, by taking proper care, may outlast and do more and better work than those naturally stronger, but who, through carelessness, injure organs by improper use or wrong use.

**Electric Light.** — The incandescent electric light has an advantage in being readily lighted, without matches, and in giving out little heat and no bad air; but owing to its intense white light, unless colored or reduced by a screen, it is not well suited for study or other near work. For this purpose an Argand gas or kerosene mantle burner is much to be preferred, since it throws a soft, uniform, and agreeable light upon the work.

**Reading during Convalescence.** — Many eyes are ruined during convalescence. At this time the whole system is often weak — including the eyes. Still, there is a strong temptation to read, perhaps to while away the time, perhaps to make up for lost time in school work.

**Keep the Eyes Clean.** — Be careful to keep the eyes clean. Do not rub the eyes with the fingers. Aside from consideration of rules of etiquette, there is danger of introducing foreign matter that may be harmful. It is very desirable that each person have his individual face towel. By not observing this rule certain contagious diseases of the eyes often spread rapidly.

**Resting the Eyes.** — Frequently rest the eyes by looking

up and away from the work, especially at some distant object. One may rest the eyes while thinking over each page or paragraph, and thus really gain time instead of losing it.

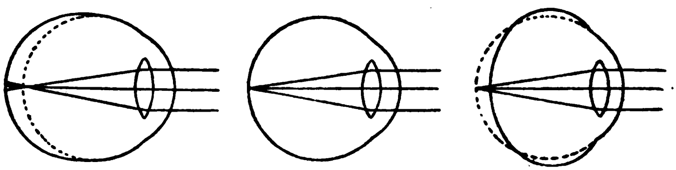
**Irritation of the Eyes.** — If one finds himself rubbing his eyes, it is clear that they are irritated. It is time to stop reading. At any rate, one should find the cause, and not proceed with the work unless the irritation ceases. If there is also pain, it may be a form of eye-strain and should be attended to. If any foreign object, as a cinder, lodges in the eye, it is better not to rub the eye, but to draw the lid away from the eyeball and wink repeatedly; the increased flow of tears may dissolve and wash the matter out. If it does not soon come out, the lid may be rolled up over a pencil, taking hold of the lashes or the edge of the lid. The point of a blunt lead pencil is a convenient and safe instrument with which to remove the particle.

Drugs and salves should not be used on the eyes except when ordered by the physician, as they may do harm. Bathing with hot water or applying a clean cloth repeatedly rung out of hot water rests tired eyes and relieves pain and irritation.

**Near Sight and Far Sight.** — In old age the lens usually becomes less elastic and is no longer able to grow more convex. Artificial lenses (eyeglasses) are then used to enable one to see near objects clearly. Most elderly people see fairly well at a distance, but use glasses for reading or any close work. In "near-sighted" eyes, the eyeball is often too long from front to back, so the rays meet in front of the retina. Concave glasses remedy this defect. The eye may also be too short (far-sighted) and need convex glasses. The refracting surfaces (cornea and lens) may be

unequally curved, *i.e.*, cylindrical instead of lens-shaped, causing astigmatism. For most of these defects the oculist can supply suitable glasses. (See Fig. 100.)

**Consult a Reliable Oculist.** — If there is any continuous trouble with the eyes, consult a reliable oculist. Many headaches are due to eye-strain, the real cause being unsuspected. If a child has frequent headaches, it is well to have the eyes examined. Many persons injure their eyes by not wearing suitable glasses. On the other hand,



(2) Near-sighted Eye (1) Normal Eye (3) Far-sighted Eye

Fig. 100. — Defects in eyesight

Notice the shape of the eyeball in each case

do not buy glasses of peddlers nor of any but *reliable specialists*. One may ruin the eyes by wearing glasses that are not suitable.

**Effects of Alcohol and of Tobacco on Sight.** — Impaired vision is a frequent result of the use of either tobacco or alcoholic drink, oftener of both combined. A peculiar disease known as the " cigarette eye " has been described as a dimness or a film-like gathering over the eye, which appears and disappears at intervals. It can only be cured by long treatment and entire disuse of tobacco. The Belgian government once made an investigation into the cause of the prevailing color blindness, and the testimony of experts was that the use of tobacco was one of the principal causes.

## Hearing

**Source of the Sensation of Sound.** — In organs of special sense, the sensory nerve endings, *e.g.*, papillæ, ciliated cells, rods and cones, are directly exposed to the outside stimuli. With the organs of hearing this is not the case. The human ear is affected by pulsations or waves in the air, caused by some sounding, that is, vibrating body; *e.g.*, a violin or a drum.

To understand how any vibrating object causes waves in the air and produces sound, see Fig. 101. Also recall the circles of waves produced by a stone thrown into water. Sound waves in air vary in length from the fraction of an inch to as much as 60 feet.

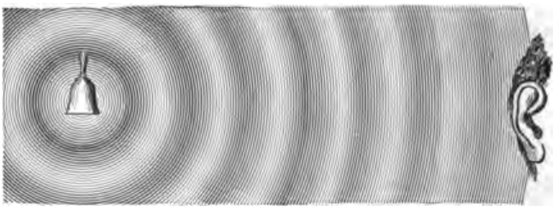


Fig. 101. — Diagram illustrating the spreading of sound waves through the air

But these sound or air waves do not reach the sensory endings of the ear nerves directly. They are transmitted through an *external* and a *middle* ear to the *internal ear*, where these nerve endings are located. Here they are surrounded and protected by the skull. (See Fig. 102.)

The necessity of air for normal hearing is shown by setting off an alarm clock that is hung in a glass globe from which the air has been removed. The hammer may be seen striking the bell, but no sound is heard until the air is let into the jar again.

**The External Ear.** — The external ear gathers the

sound waves and directs them into the opening of the ear, but the loss of the external ear does not seriously interfere with hearing. The passage leading inward from the ear extends about an inch, and is then completely shut off from the cavities beyond by a thin membranous partition, the *tympanic membrane* or drum skin. The skin of the ear dips into the external tube and lines it. It continues as a very thin layer over the membrane of the tympanum. The *auditory meatus*, as this passageway is called, is guarded by hairs, and is further protected by wax secreted by glands of the lining.

NOTE. — Every one has noticed the "play" of a horse's ears; both forward, indicating alertness to some approaching object, and, as the driver urges the horse on, one ear is turned back to catch his words, while the other ear, still turned forward, is ready for any sound in that direction.

**How the Middle Ear Works.** — The air waves act like a series of beats on the tympanum. Inside the tympanic membrane is the cavity of the middle ear, containing air.[1] The movements of the tympanum are conducted across this chamber by three small delicately-articulated bones, stretching from the eardrum to an opening in the inner ear. The names of the bones, hammer or *malleus*, anvil or *inchus*, and stirrup or *stapes*, are derived from the corresponding objects they are supposed to resemble. In the case of the stirrup the resemblance is truly remarkable. The hammer is attached to the inner surface of the membrane of the tympanum, and the stirrup is fastened by its base in an oval opening in the wall of the internal ear.

[1] It is well to call attention to the fact that the air in the middle ear, though necessary for the proper action of membrane and ossicles, does not conduct the vibrations; the bones are for this.

**The Eustachian Tube.** — The middle ear communicates with the pharynx by means of a narrow tube named, from its discoverer, Bartolommeo Eustachio, the *eustachian* tube. It admits air to equalize the pressure on the two sides of the tympanic membrane.[1] This tube is probably closed

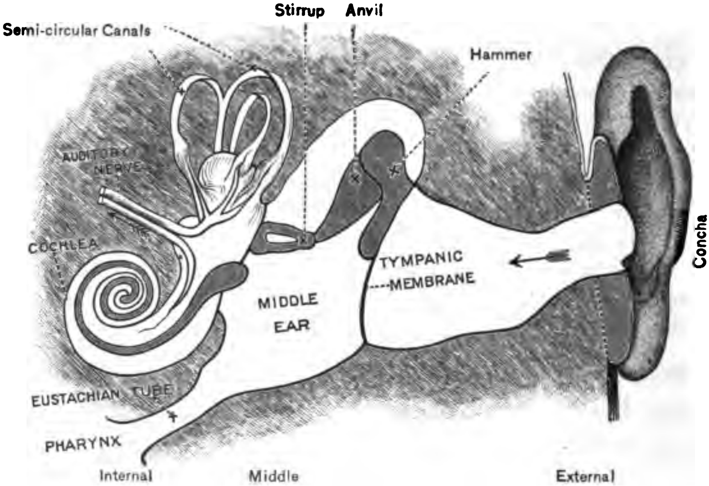



Fig. 102. — Diagram of the ear

most of the time, but opens when we swallow. During the firing of large cannon those near open their mouths. How would this prevent the injury of sudden pressure on the outside of the eardrum? In catarrhal conditions of the throat, the eustachian tube is filled by mucus, and unequal air pressure on the tympanum causes buzzing.

**Work of the Internal Ear.** — The internal ear consists of several complicated cavities and tubes which contain a

[1] By holding mouth and nose with the hand while swallowing vigorously one can feel the eardrums pressed outward. Fig. 18 shows where the eustachian tube enters the pharynx.

liquid in which the nerves rest. The principal cavity is the cochlea, or snail-shell cavity, in which the nerve endings are placed. The movements of the stirrup set the liquid of the *cochlea* into vibration, and the vibrations of the liquid start nerve impulses in the fibers of the auditory nerve, and when these nerve impulses are received and interpreted by the brain, we have the sensation called sound.

**The Equilibrium Sense.** — Probably most of the senses, especially sight and the muscular sense, contribute to the maintaining of the equilibrium of the body by giving information as to position, motion, etc. There seems to be good evidence that the semi-circular canals inform us as to changes of the position of the body, and they are regarded as the organ of an "equilibrium sense." The fact that one of these canals is horizontal, and that the two vertical canals are at right angles to each other, strengthens this belief. It is thought that each of these canals detects movements in its own plane. The experiment has been made of placing a man on a table that easily turned; with the eyes shut the subject could usually detect fairly well the changes of position from rotation of the table. What is known on the subject comes partly from observation in cases where these parts are diseased, which, in itself, does not cause loss of hearing. (See Fig. 102.)

Only that part of the auditory nerve which is distributed in the "snail shell" of the ear is now supposed to have to do with hearing. It is no longer believed that the semi-circular canals are concerned with the process of hearing.

**Limitations of Hearing.** — In some experimental laboratories there are instruments for making 16 and even 18

vibrations per second, but few people can perceive these vibrations at all. While the lower limit for ordinary hearing of musical tone is 32 vibrations per second, the upper limit is nearer 32,000 vibrations per second, mere "squeaks," like the chirp of a cricket, one would say. This means that below 32 vibrations per second, the sounds do not link themselves together as notes. There are insects whose notes have never been heard by man, but they are believed to make sounds, as their mates have hearing organs. The ear is more susceptible to the human voice than to any other sound.

**The Hygiene of the Ear.** — In cleaning the ear no hard instrument should be used; even the finger nail may do harm. A moistened cloth should be used. In washing the ear it should be thoroughly dried before being exposed out of doors, especially to a cold wind. It is not well to stuff the ears with cotton. If there is any trouble with the hearing, of course a physician should be consulted without delay.

**Colds and Deafness.** — A cold often produces inflammation of the mucous membrane of the pharynx. This inflammation may extend along the eustachian tube to the middle ear and affect the hearing. Alcoholic liquors are said to injure this sense organ, as they do others.

## QUESTIONS FOR REVIEW

1. What is the relation between the brain and the mind?
2. What relation is there between the development of the brain (mind) and the training of the organs of special sense?
3. What do general sensations tell us?
4. Name some general sensations.
5. What are the organs of special sense?

6. What are the three kinds of nerve stimuli that normally affect the skin?

7. What are the end-organs in the skin?

8. How have we learned that there are separate nerve fibers for temperature and for touch?

9. What use in having the sense of touch in the tongue?

10. What kind of substances can we taste?

11. What are the real taste organs?

12. What are the uses of the sense of smell?

13. What action of the breathing organs is necessary to catch faint odors?

14. Why can some animals smell so much keener than others?

15. What are eyespots? What may we learn from them?

16. What are the parts of the eye?

17. Which is the most important part of the eye? Why?

18. What are the uses of the parts other than the lens?

19. What advantage in having a lens that can change its curvature?

20. How is the change, called accommodation, brought about?

21. What reasons can you give for the statement that the accommodation is brought about by reflex action?

22. Why is near vision, such as reading, fatiguing to the eye?

23. What is meant by the "area of distinct vision"?

24. Why does this area make movement of the eye necessary? Explain fully.

25. What is meant by stereoscopic or binocular vision? Give an illustration of its value.

26. Why is reading out of doors likely to be harmful to the eyes?

27. In what direction should the light come for near work or reading?

28. What are the parts of the organ of hearing?

29. How do we know that air is necessary for carrying sound waves to the ear?

30. How are the vibrations carried from the eardrum (tympanum) to the inner ear?

31. What is the use of the air in the middle ear? How does it enter there?

32. How are sound waves carried to the nerve endings in the inner ear?

33. What are organs of equilibrium, or balancing organs? How was their function learned?

34. Why are colds bad for the ears?

35. To what sound is the human ear most susceptible?

## EXERCISES

*The Sensory Function of the Skin.* — 1. To find on what organs the skin has the keenest feeling: The skin is gently touched with the points of a pair of dividers, separated or brought together until they can just be felt as two points. This distance is measured in millimeters or fractions of an inch, and constitutes the relative value of the area tested, as the back of the hand. In this way the forehead, cheeks, lips, and finger tips may be tested. Which is the most sensitive; which the least? Confirm your conclusion by touching the same areas with a moderately rough object. How may the difference in sensitiveness of the back of the hand and the finger tips be explained? (Hairpins with crossed ends may be used in place of dividers.)

2. Another method is to make an ink dot with one point of dividers on the area to be tested and, looking away, to try to place the other point of the dividers, by "feeling," on the same spot. The nearness with which one can locate the spot touched is the measure of sensitiveness. By either method compare the sensitiveness of the little finger tip with that of the thumb or index finger. Practice educates the sensitiveness of the nerve endings, but does not increase their number.

3. To determine another sensation besides touch: The forehead or back of the hand is touched with a metal or other smooth surface (a nail) and the first impression (sensation) is at once recorded. What is it? Now the nail is held in a cup of warm water, and then applied to different parts of the forehead or back of the hand. What is the sensation now? One word will express the sense about which you have thus learned.

4. To determine whether our sense of heat and cold is thermometer-like, actually to tell degree of heat, or dependent on the cold or warm

condition of the skin: Three cups are filled, one with very warm water, one with cold, and one with water intermediate between the two. A finger, held for a time in the cold water, is dipped into the middle cup. How does the water in the middle cup feel to this finger? Record this. Another finger is now held in the very warm water and then dipped into the middle cup. How does the water in the middle cup feel to this finger? If there is any doubt, reverse the order, using the very warm water first, or with a thermometer test the water in the middle cup, to see if it has changed temperature as the feeling of the fingers would indicate. Why do we frequently think the house "too warm" when we come home in winter time?

*Tasting.* — 5. To learn in what condition food must be in order to be tasted: Wipe the tongue dry with a clean paper or cloth, and while it is held out of the mouth sprinkle on it some dry sugar. Notice at *once* the amount of sweet you can taste. Presently the sugar dissolves in the saliva. What is learned?

6. To illustrate the dependence of flavor upon odor: Smell of onion, apple, or cinnamon bark. Now close the nose by pinching it and lay bits of either of these substances on the tongue, pressing them against the roof of the mouth. Can you now perceive the flavor? Now open the nose and notice the result. How are the flavors of food relished?

7. To learn the effect of temperature upon taste: Rinse the mouth either with iced, or with very cold water. Then sweet or bitter foods may be tasted. How does cooling the nerve endings in the tongue affect their action?

*Seeing.* — 8. To learn to focus lenses: Any magnifying lens or even a lens of a pair of glasses may be used. Move it toward and away from the object viewed, until the picture is as clear as you can get it. If there are lenses of different thicknesses, find whether the thicker ones have to be held farther away from or nearer to the object. If half of an old opera glass can be obtained, it has a bi-convex lens, a plane concave, and a bi-concave lens.

9. To show how a lens focuses light to a point: A few drops of milk are added to a tumbler full of water, which is set in a pasteboard box taller than the tumbler. A hole is cut in one side of the box at the surface-level of the water, and a lamp or candle placed outside so that it is opposite the hole. If, now, a tripod magnifier or almost

any short-focus lens is held vertically near the side of the glass, a cone of light can be focused on the opposite side of the tumbler. With a stereopticon this exercise can be made much more effective.

10. To focus the eye-lenses: If you will hold up one index finger at reading distance from your eyes (about 15 inches) and the other 8 or 9 inches beyond the first, you cannot see both plainly, but by a change in the lens of the eye, each finger can be plainly seen in turn. This change in the lens is called *accommodation*. It is the natural focusing of the lens.

11. *The Blind Spot.* — In this exercise shut the right eye, and be careful not to let the left eye waver.

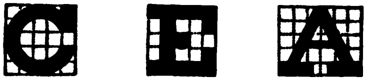
★ Read this line slowly. Can you see the star all the time? If the star does not disappear before reaching the end of the line, let the eye travel across to the right-hand edge, or hold the book nearer the face. In the human eye the optic nerve enters the eye not in the center, but nearer the nose, so that in turning the left eye toward the right at the proper angle, the image of the star falls upon the spot where the optic nerve enters. As this spot is insensitive to light, the star no longer appears. Falling on the optic nerve itself has no effect in giving a sensation of light. And if the light falls on the spot where the optic nerve enters the eyeball, we see nothing. Hence, this spot is called the *blind spot*.

12. How the amount of light entering the eye is regulated: Hold a hand-glass between the face and a well-lighted window. Note the size of the pupils. Quickly turn toward the darkest part of the room. We see, what we have all noticed in watching the eyes of a cat, that when subject to a bright light the pupil is small, but with less light the pupil is larger.

13. To learn the use of the two eyes in judging distance: Hold one index finger about eighteen inches from your face. Close one eye and move the other index finger from near the open eye outward until you think it is the same distance from the eye as the other finger. Now bring the fingers together. Do they meet? Try with both eyes open. What have you learned?

14. To learn if your eyes are normal: If there is a Snellen's chart, or other eye-testing chart, hang it on a well-lighted wall and stand 20 feet away. Holding a card or book over the left eye, face the chart and note the smallest letters that you can easily read. If you can

read the letters in the 20-foot line, your right eye is normal. Test the left in the same way. Black letters $\frac{5}{16}$ inches high on a white card hung at 20 feet will answer the same purpose. Which eye is normal? Is either short-sighted?



Snellen's Test Letters

These should be seen distinctly by a correct eye at a distance of twenty feet

15. To test for astigmatism: Eye charts have a group of radiating lines for this purpose. Test each eye separately. If some of the lines appear indistinct or broken, you have astigmatism in that eye. If there is no eye chart, the figures on a clock dial will do for this test. In case you discover defects under either 5 or 6 a reliable oculist should be consulted.

*Hearing.* — 16. To learn the cause of sound: A fine wire (several feet long) is stretched tightly between two fixed points. The wire is pulled to one side and released. If you close your eyes when it is pulled to one side, can you tell when it is released? How? On opening the eyes again can you see how the wire moves? In your statement first use your own words for the motion, then call it *vibration.* This illustrates how all kinds of sounds are produced or caused. Do the vibrations of the string reach the ear? What does the vibrating string strike that does touch the ear? This holds true for all sound reaching the ear normally.

NOTE. — Another way (not normal) of conducting sound to the ears may be illustrated by holding a watch or any sounding body against the teeth while the ears are externally closed. How is the sound now conducted to the ears? One kind of ear trumpet is made on this principle.

17. To learn if air is necessary to carry sound to the ear: An electric bell, or an alarm clock, is placed in the air-tight receiver of an air pump. As much of the air as possible is pumped out of the bell jar. The electric bell (alarm clock) is set off as soon as most of the air is out of the bell jar. The hammer is observed striking the bell. How does it sound? When air is again admitted what difference does it make? What does this exercise show?

18. To understand the use of the external ear: The whole class are to place their hands against the side of the head, the edges just in

front of the ears, the thumbs turned outward and the palms backward. Now while some one is talking, or any noise of constant loudness is going on, the hands are held behind the ears as one does in listening to a distant speaker. Then the hands may be alternated slowly to insure better understanding of this exercise. The individual pupil can do the same alone.

19. The so-called "noises of the sea," the rustling sounds heard when one holds a sea shell to the ear, are apparently intensified sounds that we ordinarily do not notice. The same effect may be produced by holding a tumbler over the ear in place of a sea shell.

20. To learn if the hearing of each ear is approximately normal: An ordinary watch is placed five feet from a chair in which the pupil sits, turned 90° from the direction of the watch. This must be done when the room is quiet. If the watch has to be brought within three feet of one ear, that ear is $\frac{3}{5}$ normal. In a quiet room many pupils can hear the watch at eight feet, and some at ten feet. To prevent subjective results on the part of some pupils, the watch may be muffled at times with both hands by the teacher. Each ear is to be tested separately.

# CHAPTER XIV

## THE VOICE AND SPEECH

**The Historical Development of the Voice.** — Among animals the ability to produce sounds, probably mating sounds, went hand in hand with the development of hearing organs. In some fishes, sounds are produced by rubbing together certain structures in the air bladder. In frogs there are vocal cords. Ordinary reptiles have no voice, though most of them hiss. In birds, voice is produced by a vibratory, tongue-like membrane in the windpipe near the lungs — not in the " throat," as is commonly supposed. In mammals or man the sounds are produced by the vibrations of a pair of membranous folds — the vocal cords — in the upper end of the *trachea*.

**Work of the Larynx.** — Instead of rings of cartilage in the upper end of the trachea, there are plates of considerable size. This part of the trachea is the *larynx*. The movements of these cartilages are brought about by muscles. In front, these muscles connect the larynx with the *hyoid* bone above, and are so placed as to narrow the lower part of the larynx. At the back of the larynx are various muscles which are so attached to the cartilages as to alter the shape of the larynx. (See Fig. 103.)

**What we can learn from Our Own Throats.** — We can learn a little from the observation of our own mouths and throats. The projection of the throat known as " Adam's apple " is one angle of the thyroid cartilage. A ridge may be felt running downward from the projecting angle. Above the Adam's apple a depression may be felt.

Press the tip of the finger lightly into this depression and perform the act of swallowing. It will be noted that the Adam's apple is drawn upward and closer to the bone above the depression. This bone is the hyoid bone; it is connected with the larynx below the base of the tongue. Below the thyroid cartilage another cartilage may be felt, the *cricoid* cartilage. Below this is the windpipe with its rings of cartilage. The general form of the whole larynx may be felt in a person not overburdened with fat.

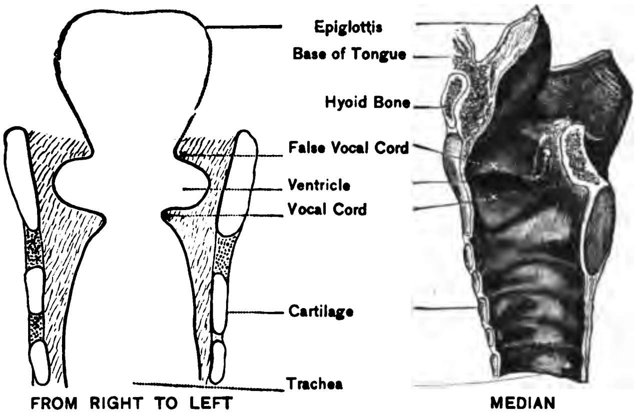



Fig. 103. — Longitudinal sections of the larynx

By depressing the tongue and looking into the mouth the tip of the epiglottis may possibly be seen at the base of the tongue. Beyond these points we cannot learn much without a small mirror. One set obliquely on a handle (like those used by dentists) may be inserted through the mouth so that the larynx can be seen from above.

**Position of the Vocal Cords.** — Within the larynx are the *vocal cords*. These are bands of elastic tissue which stretch from front to back of the larynx, being brought together in front but separating at the back. These cords are covered by the lining mucous membrane. (See Fig. 104.) The slit between them is known as the *glottis*. Above

each cord is a depression, and above this is a somewhat prominent fold known as the false vocal cord.

**How the Vocal Cords Work.** — During quiet breathing the edges of the vocal cords are rounded and thick, and are widely separated at the back. To produce voice, the muscles pull the cartilages so that the vocal cords come more

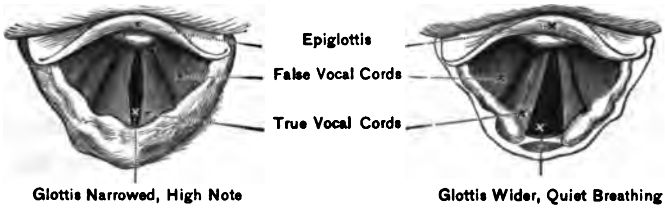



Fig. 104. — The larynx, as seen by means of the laryngoscope, in different conditions of the glottis

closely together and are stretched; their inner edges become thinner, and vibrate. The increased tension of the cords makes a higher pitch of the voice.

Children who are born deaf do not make articulate sounds, never having heard any to imitate. They may often be taught to speak by feeling the throat of one speaking so as to imitate the movements of the larynx.

**Illustration of the Vocal Cords.** — The principle of the action of the vocal cords can be illustrated by the common toy known as the squeaking balloon, or "squawker." Here the air is driven out past a band of rubber stretched across the inner end of the tube. If instead of one band with both edges free, we were to tie on the inner end of the tube two bands of rubber, each covering the outer edge of the tube, leaving the inner edge of the rubber free, and with the two bands touching at one end and considerably separated at the other end, we would have a pretty fair imitation of the larynx and vocal cords.

**Reënforcement of Vocal Sound.** — As in many musical instruments, the vibrations of the membrane alone would

be too feeble to have much effect. In the violin, piano, drum, etc., the vibrations are *reënforced* by the vibration of a body of air contained within. So here the vibrations of the cords are reënforced and modified by the air spaces above — the pharynx, the mouth, and the nose.

**Loudness of Voice.** — The loudness of the voice depends on the *force* with which the air is driven past the cords, together with the size and condition of the cords themselves.

**Pitch of Voice.** — *Pitch* depends on the rapidity of the vibrations, which is determined by the length of the cords and their tension. Other things being equal, the size of the larynx would determine the pitch.

**Singing.** — Beginning at the lower part of his register, a singer can run up the *scale* some distance without a break, but then, to reach his high notes, must pause, change the larynx, and begin again. The vocal processes at first are turned in, but do not meet, and the *whole* length of the cord vibrates. When the pitch can no longer be increased, the cords are further rolled in until they touch; this shortens the cord and therefore gives a high note, and the gradual tightening of the cord will give a new series of notes.

The *range* of the human voice (in one person) is about three octaves, from E on the unaccented octave, with about 80 vibrations per second, to C on the thrice-accented octave, with 1024 vibrations per second. Great singers, of course, exceed this range. An ordinary bass voice ranges from 88 to 297 vibrations per second, and a soprano from 248 to 792 vibrations.

**Voice and Speech.** — The larynx by itself produces vocal sound merely. In speech the sounds produced in

the larynx are much modified by the lips, tongue, teeth, cheeks, etc. We have voice as soon as born, but we only gradually acquire the power of speech. Mammals, birds, and some of the lower vertebrates have voices, but they have not speech. This distinguishes man from the animals below him, though perhaps some of the higher apes have speech in a slight degree.

**Culture of the Voice.** — The voice and speech are very susceptible of culture, and nearly all voices may improve by proper cultivation. A cultivated voice and careful, distinct speech are very desirable accomplishments, and are not nearly so common as they ought to be. We delight in fine singing, and many strive to cultivate this art; but not so many try to learn to talk so that it is a pleasure to hear them.

**Change of Voice.** — At about the age of fourteen a boy's larynx increases in size and the voice changes, becoming deeper and heavier. During the change the falsetto often breaks in upon the ordinary voice, the voice being said to "crack."

**Differences between Voices.** — Since no two throats are exactly alike, no two voices sound just the same. The size and shape of the pharynx, the shape and position of the teeth and lips, the condition of the mucous membrane of the passages generally, all affect the sound, and give it its "*quality*," by which we distinguish one voice from another, even if both have the same pitch and the same degree of loudness. Quality is due to overtones.

**Whispering.** — If the mucous membrane covering the vocal cords is inflamed, or covered with too much mucus, hoarseness is likely to result. In whispering there is no true voice. Thus we have speech without voice, while in animals there is voice without speech. To produce a whis-

per the *glottis* is considerably narrowed, but the cords are not stretched to produce a thin edge, and air forced between them is set into irregular vibrations. Vowels may be produced in whispers because the number of irregular vibrations offers some which are reënforced into the vowel sounds by the shape of the mouth. In whispering, the distinction between such consonants as *p* and *b*, *t* and *v*, is imperfect.

### QUESTIONS FOR REVIEW

1. What was the probable origin of the voice?
2. What is the lowest animal having vocal cords?
3. What are the important parts of the larynx or voice box?
4. How do the vocal cords produce sound?
5. Why do deaf children frequently have no voice?
6. How can they be taught to speak if their vocal cords are good?
7. What is the explanation of "pitch"? How does loudness differ from pitch?
8. What is the range of the human voice?
9. What is the difference between voice and speech?
10. By what do we tell different voices?
11. What are the interesting facts about whispering?

# CHAPTER XV

## ALCOHOL AND NARCOTICS

**Fermentation and Alcohol.** — If a glass of sweet cider is set in a warm place for a few days, it will probably be observed that bubbles of gas are given off and the cider will now have a sharp, pungent taste. The gas is carbon dioxide, and the new taste is chiefly due to it and to *alcohol*, formed from the sugar. The same change would be likely to occur in a moderately strong solution of sugar, and in sweet fruit juices. Sweet liquids undergoing this change usually become frothy, or "work," as we say, and at the same time acquire a sharp taste. This change is due to ferments and the process is called fermentation.

**Plant Ferments.** — Most higher plants store ferments with the starch in seeds and tubers, or else the plant germ in the seed forms them. At the proper time these ferments convert the starch into sugar, and if yeast germs are also present they form a ferment that changes the sugar to alcohol. Besides yeast there are many other organisms which cause similar changes by their ferments. For instance, putrefaction or decay is fermentation of substances containing nitrogen caused by a kind of germs called bacteria. The formation of vinegar is also due to bacteria. Formerly the organisms themselves were thought to be the ferments.

**The Nature and Work of Yeast.** — Any sweet liquid in which alcohol is produced is found to contain yeast. Yeast is a microscopic, one-celled plant, oval in shape,

which produces a ferment. Common baker's yeast represents one group of these organisms.

It has been clearly proved that yeast is the cause of the above change, some of the more manifest reasons being as follows: (1) Yeast may always be found in liquids undergoing alcoholic fermentation. (2) Yeast is killed by boiling. If such liquids as have been mentioned are thoroughly boiled and placed, while boiling hot, in a perfectly clean jar and sealed air-tight, they will keep indefinitely without any fermentation of this kind. (3) Yeast added to such sweet, boiled liquids after cooling makes certain this form of fermentation.

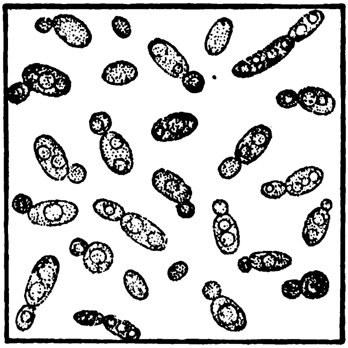


Fig. 105.—Yeast plants

Notice how they grow—multiply—by *buds*. The smaller ones are freed buds. The bud in the upper right hand corner is ready to separate from the mother cell. All greatly magnified.

Yeast cells are not killed by drying. They become dry and float as part of the common dust of the air. They are still alive, and if they fall into a sweet liquid, especially if the liquid is not saturated with sugar, they begin to grow. In their growth they secrete a ferment which causes sugar to break up, or decompose, forming at least two substances, carbon dioxide and alcohol. This change produced by the ferment is called alcoholic fermentation. A small quantity of yeast has the power of changing a large amount of sugar into carbon dioxide and alcohol. Then, too, we must remember that its growth, similar to that of bacteria, is so rapid that a small number of yeast cells soon becomes a large number.

NOTE. — In bread-making the ferment stored with the starch in the grains of wheat changes some of the starch to sugar in the dough. Then the yeast added in "setting the sponge" brings about the fermentation of sugar, producing alcohol and carbon dioxide. This gas puffs up the dough, making the bread "rise," *i.e.*, making it light and spongy. What becomes of the alcohol that is formed in this process?

**"Temperance Drinks."** — Many well-meaning persons use the various preparations called "temperance drinks," without realizing that some of them are made with yeast and in their preparation undergo fermentation, thereby producing alcohol, though not ordinarily in large amounts. By giving such drinks, *e.g.*, home-made root beer, to children, a liking for alcohol may be cultivated and the beginning of a bad habit made. Soda water, grape juice, and commercial ginger ale are not fermented.

**Fermented Drinks.** — All alcoholic liquors are the result of alcoholic fermentation of various substances. Such liquors may be classed in three groups — wines, malt liquors, and distilled liquors.

**Wines.** — The wines are the result of fermentation in the juice of the grape or other fruit which contains sugar. This fermentation was, in all probability, discovered very early by the human race, for we find it in use among nearly all races of men, and accounts of it are in the early records of history. But it was not until the microscope was invented that its cause was known.

When alcohol accumulates in the fermenting liquid to the amount of 14 per cent, it kills the yeast germs; consequently no natural wine can contain more than this amount. Wines are classed as light wines and heavy wines. The light wines contain from 5 to 12 per cent alcohol. The heavy wines include all wines with more than this amount,

and have had brandy, or other spirit, added to them, having from 16 to 25 per cent, or even more, alcohol.

**The Danger in Wine Drinking.** — Because some of the wines contain a relatively small percentage of alcohol, there is a common delusion that there is not much harm in drinking them. Let us consider three points regarding this. (1) We do not argue or act in the same way in regard to other substances that are known to be harmful. We do not venture to take small doses of arsenic or phosphorus, saying, "Oh! a little will not hurt me." The poison is there just the same and will have its effect. (2) In small quantities the alcohol in the wine has the power to fix the alcohol habit, which is cumulative and leads to a desire for more which is almost impossible to resist. (3) Because it leads to the use of stronger drinks.

**Cider.** — Cider has also been called "apple wine." Besides this there is a cider made from pears, called perry. It is not a good thing to keep sweet cider about the house. It is pretty sure to ferment and as soon as it has a tang, alcohol is forming. Hard cider contains from 2 to 10 per cent of alcohol. It is not only decidedly intoxicating, but experience has proved that some forms of disease result from the habitual use of this drink. It also leads to the desire for stronger drinks.

**Vinegar.** — After sweet cider has fermented — or become "hard" as we call it — it usually passes on to become vinegar. This change is another form of fermentation, due to another kind of ferment. The formation of vinegar is likely to take place in any weak solution of alcohol-fermented liquor. In this fermentation acetic acid is produced, hence it is called the acetous fermentation. It is interesting to note that the word "vinegar" comes from

the French *vin* (wine) and *aigre* (sharp or sour), as vinegar was formerly made by this secondary fermentation of the lighter wines.

NOTE. — Vinegar made from cider is a more wholesome condiment than that manufactured from "pure acetic or sulphuric acid."

**Malt Liquors.** — These are obtained from the small grains, especially barley, by soaking the grain and keeping it warm, thus causing it to sprout. The plant germ in the seed during this process forms a ferment that converts most of the starch into glucose or sugar. At this stage heat is applied to kill the little plants (sprouts), otherwise the sugar would be used up by them. Next the sugar is extracted with water, and yeast is added to convert the sugar into alcohol. This makes beer, containing about 2 to 5 per cent of alcohol. Hops and other substances are usually added. Although the percentage of alcohol in beer is low, the effect of beer drinking is marked. As in the case of wine, often the drinker takes such enormous quantities of the liquor that the total amount of alcohol introduced into the system is large, and the effect correspondingly pronounced. In the case of many beer drinkers there is apparent a continual state of heaviness or lethargy, a sort of perpetual stupefaction, which points significantly to the narcotic effect of alcohol. It is said on good authority that in the city of Munich it is rare to find a sound heart or sound kidneys; and perhaps this is typical of many large cities where beer drinking is so widely prevalent.

**Distilled Liquors.** — Distilled liquors, or *spirits*, are obtained from the wines and fermented liquors by the process of distillation. This process depends on the fact that alcohol boils at 173° F., while water boils at 212° F.

The *still* consists of a large boiler with a closed top, and a tube rising from the top. This tube passes through a reservoir which is kept filled with cold water. On heating the fermented liquid in the still up to 173° F., the alcohol is converted into vapor. As this passes along the cold coiled tube the vapor is condensed. Thus the alcohol is separated from the water and other liquids, which boil at a higher temperature. By distilling wine a large part of the water is left behind, and brandy is the result. Whisky is made by distilling fermented grains, especially rye and corn, while rum is manufactured by the distillation of fermented molasses. Most of the distilled liquors contain from 40 to 50 per cent of alcohol. By repeated distillation and rectification 99 per cent alcohol is obtained. Pure alcohol is not largely used, the ordinary commercial alcohol being about 91 per cent alcohol. The effects of alcohol on the human system will be treated a few paragraphs later.

**Common Kinds of Alcohol.** — Ordinary alcohol is also called *ethyl*, or grain alcohol, to distinguish it from *methyl*, or wood alcohol. The latter is made by the distillation of wood and is a violent poison. Because of the government tax on distilled liquors, alcohol had become an expensive article for use in the arts and trades, such as preparing paints, dissolving gums, and as a fuel. Denatured alcohol is made to meet this demand by adding to the ethyl spirits enough wood alcohol to poison it. Both wood alcohol and denatured alcohol serve all purposes except for human use and for this reason are not taxed. When taken by mistake they prove fatal.

**Properties of Alcohol.** — Alcohol is a clear liquid, about four-fifths as heavy as water. It boils at 173° F., and does not freeze above – 200° F., so it is often used instead of

mercury in cheap thermometers. Alcohol dissolves resins, fats, and many substances which are insoluble in water. It is composed of carbon, hydrogen, and oxygen ($C_2H_6O$). In composition the alcohols resemble fats. In both there is only a small proportion of oxygen to the amount of carbon and hydrogen. For this reason they burn with great readiness and produce a large amount of heat. Alcohol burns with a nearly colorless, but very hot, flame, and does not produce soot; hence it is very useful for small cooking, soldering, and for jewelers' work. Grain alcohol is also extensively used in making up medicines, hence the danger in patent medicines that are often taken in large quantities and lead to the alcohol habit.

**Physiological Effects of a Moderate Dose of Alcohol.** — A moderate dose of diluted alcohol or ordinary alcoholic drink usually has about the following effects, especially upon those not accustomed to its use: First, a dilation of the blood tubes of the face and of the mucous lining of the stomach; for a very short time a quickened, and perhaps more forcible, heart beat; nervous excitement, shown by restlessness and talkativeness; followed by more or less dullness or drowsiness, usually followed by a depressed feeling on the next day.

**The Danger of Moderate Use of Alcohol.** — It is time to ask the question, What effect does the continued use of alcohol have upon the body?

No one denies that the use of alcohol may, and often does, create an appetite for more, and that this appetite frequently becomes uncontrollable. If one eats a sufficient amount of bread to-day, he does not, in consequence, crave a larger amount to-morrow. But the appetite for alcohol grows. History is full of accounts of men who thought

they could stop it when they chose. The man who says that he can take it or let it alone, usually takes it. The grip of the alcohol habit is well-nigh as relentless as the grip of death.

There is one safe rule: *Touch not, taste not, handle not.*

**Alcohol as a Stimulant.** — Until late years nearly all authorities considered alcohol a stimulant. Its effects were apparently such as to rouse the organs of the body to a higher degree of activity. But recent experiments have shown that this effect, which is of a very short duration, is not its real characteristic action. In from ten to twenty minutes this preliminary excitement begins to abate, and is followed by a period of diminished activity.

It is very evident how foolish it is for one who is exposed to severe cold to drink alcoholic liquor to keep himself warm, and the extreme danger of such a course. Members of exploring parties in cold climates have lost their lives by ignorance of, or disobedience to, this well-known rule. In the unconsciousness of drunken sleep the full narcotic effects of alcohol are seen. And it is very significant that the word by which we designate this condition, a word that was applied long generations before there was any systematic study as to how drugs affect the body, this word — *intoxication — means poisoning.*

**Alcohol as a Narcotic.** — Many of the later writers who have investigated the subject say that alcohol is not a stimulant, but always a narcotic. The effect on the arterioles is explained as follows: In ordinary conditions of the circulation, when only a moderate amount of blood is needed in any given organ, the circular muscle fibers in the walls of the arteries leading to that part are kept shortened by nervous impulses sent to them from the nerve centers

which control them, hence a moderate supply of blood. A narcotic has a paralyzing effect on these nerve centers; hence the usual impulses which would have been sent are no longer sent, the muscle fibers relax, the arterioles widen, and the part becomes flushed.

The action of the narcotic is to paralyze the nerve center from which the restraining impulses normally are sent to control the heart. Hence the rapid beat. As to the force of its beat there is difference of opinion; many maintain that it has less force than before.

Under the influence of alcohol the person says and does foolish things; he violates confidence; he proposes, and engages in, rash undertakings; his higher nerve centers in the brain are more or less paralyzed; his judgment is weakened; in short, he has lost self-control.

**In the Army and Navy.** — The Secretary of the Navy has issued an order that forbids the use of intoxicants on ships and in naval stations.

"The Secretary's orders are simply in line with our growing knowledge. The nation needs on its battleships to-day the most capable, clear-headed, cool-brained, and steady-handed men, and these men are not found among the habitual or occasional users of alcohol in any form. Entirely aside from moral or sentimental reasons, and considered simply as a scientific regulation in the interest of efficiency, this order will recommend itself to the vast majority of the American people." — *Journal of the American Medical Association.*

Dr. Frank H. Hamilton said: "It is earnestly desired that no such experiment (using liquor as a ration) ever be repeated in the armies of the United States. In our own mind the conviction is established by the experience and ob-

servation of a lifetime, that the regular routine employment of alcoholic stimulants by men in health is never, under any circumstances, useful. We make no exceptions in favor of cold, or heat, or rain."

**Testimony of a Naturalist.** — W. T. Hornaday, author of *Two Years in the Jungle*, who has had years of experience as collector in many lands, has the following to say as to the use of alcoholic drink: "Above all things, however, which go farthest toward preserving the life of the traveler against diseases and death by accident, and which every naturalist especially should take with him wherever he goes, are *habits of strict temperance*. In the tropics nothing is so deadly as the drinking habit, for it speedily paves the way to various kinds of disease which are always charged to the account of 'the accursed climate.' If a temperate man falls ill or meets with an accident, his system responds so readily to remedies and moderate stimulants that his chances of recovery are a hundred per cent better than those of the man whose constitution has been undermined by strong drink. There are plenty of men who will say that in the tropics a little liquor is necessary, 'a good thing,' etc.; but let me tel you it is no such thing, and if necessary I could pile up a mountain of evidence to prove it. The records show most conclusively that it is the men who totally abstain from the use of spirits as a beverage who last longest, have the least sickness, and do the most and best work. As a general rule, an energetic brandy-drinker in the jungle is not worth his salt, and as a companion in a serious undertaking, is not even to be regarded as a possible candidate."

**Alcohol in Mountain Climbing.** — Statistics have been collected from mountain climbers, and a large majority testify

that alcoholic drinks are injurious, or, at least, not helpful. Mountain climbing calls for a greater expenditure of energy than is realized by any who have not tried it. Aside from the natural exhaustion of such severe exertion, there is likely to be giddiness or nausea as a result of the rarefied air. The keeper of the house on the summit of Pike's Peak said that such symptoms are almost invariably aggravated instead of being relieved by taking alcoholic drink.

**Is Alcohol a Food?** — Alcohol certainly cannot build up muscle or nerve, because these tissues must have nitrogen as a constituent element, and alcohol contains no nitrogen.

Undoubtedly the best test of a food is its ability to maintain working power. Does alcohol do this?

In the above paragraphs are given the results of much experiment and observation. Alcohol has been tried in the army and navy, on the march and in camp, in hot and cold climates, in mountain climbing, in training for boxing, boating, and other athletic contests, and as a result the uniform testimony is that it fails to sustain energy, that is, *as a food it is a failure.* Experience shows that men can endure more cold and more hard labor without alcohol than with it. This has been repeatedly proved in Arctic expeditions, in the army and navy, during the hardships and exposures of forced marches and deprivations in all climates. Neither in hot nor in cold climates is alcohol necessary to health, and even its moderate use does more harm than good. The explorers in the arctics and in the tropics are alike better off without alcohol than with it.

This testimony as to the uselessness of alcohol is all the stronger on account of the chemical nature of alcohol and the claims made for it. Alcohol contains but little oxygen and burns readily and yields a large amount of energy in

the form of heat. It seems very natural, therefore, to jump to the conclusion that it will oxidize in the body and produce heat and, perhaps, other useful energy. It does oxidize in the body, but, as already shown, it causes the body to lose more heat than it furnishes, and the work accomplished during the period of its influence is less than that accomplished without it.

The fact of the oxidization of alcohol in the body does not necessarily prove that it furnishes the body energy that can be utilized, for other substances, everywhere recognized as poisons, such as muscarin and carbolic acid, are also oxidized in the body.

The fact, then, seems clear that alcohol does not furnish the body with available energy with which to carry on its daily work, without doing harm.

On the other hand, we can see how the readiness with which alcohol is oxidized in the body is plainly injurious. It is well known that most persons eat more than is needed; in fact, some of the best authorities state that the larger part of the ills of the body, especially in later life, come from overeating, or as an adage puts it, "one half of what we eat enables us to live, the other half enables the physicians to live." Now when, in addition to a surplus of food, alcohol is also taken, the ready oxidation of the latter prevents the complete oxidation of food, and favors the accumulation of incompletely oxidized waste products, which are very harmful in the system. They clog the excretory organs, especially tending to overwork, and consequently to break down, the liver and the kidneys.

**Diseases produced by Alcohol.** — The organs most directly affected and altered in structure by alcohol are the stomach, heart, liver, kidneys, lungs, and nervous system.

Even moderate drinking may affect any of these organs. Tremor of the muscles, especially noticeable in the hands, is often observed. This tremor reaches its extreme in the terrible disease known as delirium tremens. The heart often undergoes fatty degeneration, fat replacing part of the muscle. The arteries may undergo the same change. The kidneys are disordered, and one form of resulting disease is known as Bright's disease. But the most positive, and the most serious, effect of alcoholic drinks is on the nervous system, of which more will be said later.

**Predisposition to Disease caused by Alcohol.** — In many cases where the use of alcoholic drink has not actually shown a diseased condition there is marked weakness and inability to resist or throw off disease. Drinkers are much more subject to sunstroke and to many of the infectious diseases. Yellow fever is almost surely fatal to the intemperate. Some forms of pneumonia are more likely to attack the intemperate. The insidious nature of alcohol and the evil effects of moderate drinking appear when the body is attacked by disease. The body is found to be undermined and sapped of its strength at the very time when a reserve fund of vitality is needed to ward off the attack of disease.

## The Social Effects of the Liquor Habit

**Alcoholic Liquors and Character.** — Serious as are the effects of alcohol on bodily health, and prejudicial as it is to all business prospects and what we usually call success, still more fearful are the effects, through the nervous system, on the mind and *character*. Although a later section gives some attention to this matter, certain phases of the subject may be treated here.

**Alcohol and Poverty.** — No one needs to be told that a large share of the *poverty*, everywhere so common, is due to the drinking of alcoholic liquors. Much of the earnings are frequently spent for liquor; the man's working capacity is diminished, his work becomes irregular, and so unreliable that the drinker often fails to obtain employment when he is sober.

**Alcohol and Crime.** — Every one knows from observation and newspaper reports that much of our daily *crime* is due to alcohol. Without quoting figures it may be stated that carefully collected statistics show that a large per cent of the inmates of our jails, reformatories, and penitentiaries are brought to such places through the influence of alcohol.

**The Business Man's View.** — Many firms and corporations now refuse to hire any one who is known to indulge in alcoholic liquors or to frequent saloons. Drinking makes men *unreliable*, and the wise business man will not intrust matters of importance — and all business is important — to those on whom he cannot rely. No boy or young man can afford to risk his position and his reputation by taking a single drink of liquor.

**The Delusive Nature of the Effects of Alcoholic Liquors.** — Alcohol is one of the most delusive substances known to man. The feeling of increased warmth after taking alcohol is due to the greater amount of blood in the skin where the nerve endings are affected, or to the deadened sensibility to cold, or to both; test by the thermometer shows that the body's temperature is lowered.

After taking alcohol a person may feel stronger; actual test of strength shows diminished muscular power.

Fatigue seems to have been done away with because

sensibility is blunted; any form of drowsiness would produce the same result.

Hunger appears to be satisfied through the action on the nerves of the stomach; but the body's need of food has not been satisfied. Thirst may seem to have been allayed; but only soon to return intensified. What usually passes for wit, under the influence of alcohol, is ordinarily the silliness of the tipsy; under this influence the person overestimates his wisdom, while others can easily see that his judgment is warped. He may fear danger less than before, but he should not be called brave; he is *less* sensible of danger, and he has become rash or even foolhardy.

In all these cases sensibility is lowered, and the nerve centers, especially the higher centers, have become more or less deadened. For a short time the blood and the brain run riot, the reins of judgment having been thrown overboard. Power has not been gained, but *control has been lost.* Alcohol is not the "elixir of life," it is the "fountain of death."

**The General Danger of Using Alcoholic Liquors.** — The danger is especially great where there is a latent hereditary tendency to inebriety or insanity. Many individuals, on finding a drug which exhilarates and banishes the weight of oppression by which they are borne down, are tempted beyond their power of resistance, even though they know that the reaction will bring them into a worse condition than the one from which they sought relief. The pressure of modern life, and the intensity of the struggle for a living, brings about a condition of nervous strain that is fraught with great danger. Every *thinking* man should see that to use alcoholic drink for the relief of such a condition is like cutting off a finger to cure a felon.

## Effects of Alcohol on the Nervous System

"Oh, that man should put an enemy into his mouth to steal away his brains!" —*Shakespeare.*

**The Effects of Alcohol on Nervous Tissue.** — The physiological effects of alcohol which have been considered in connection with the muscles, circulation, digestion, etc., are quite subsidiary to its effects on the central nervous system.

It is difficult to understand the extreme delicacy of organization of the nervous system. We can readily see how thoroughly nature has guarded this tissue by placing it in the most protected places in the body. But even after we have considered this point, we are not yet ready to comprehend the fine texture and sensitiveness of this tissue above all others. It is this high degree of susceptibility of the nervous system that renders it peculiarly subject to the effects of alcohol. The injury done to the brain by alcohol may not be readily discernible; but as the brain is so delicate we cannot expect to trace the changes in structure as we might in some of the larger organs of the body. For instance, the rupture of a small blood-tube in most of the tissues of the body results in a small clot, which ordinarily is a matter of no special consequence; it forms a "black-and-blue spot," which is hardly more than a temporary inconvenience, for it does not ordinarily interfere with the function of the organ. It is soon absorbed, and all traces of it pass away. Not so with the brain: a clot produces pressure on the delicate nervous tissue, which results in paralysis or death.

**Effects of Small Doses of Alcohol on Mental Operations.** — The common but erroneous idea is that alcohol stimulates the brain to a higher degree of activity. The

liquor has paralyzed the smaller blood tubes, thus allowing the brain to be flushed with blood. Careful experiments show that any temporary increase in mental activity, following small doses of alcohol, is always at the expense of accuracy and power. An eminent professor in Leipsic has said that the German students could do twice as much work if they would let their beer alone. Dr. August Smith has found by experiment that moderate, non-intoxicant doses of alcohol lowered his ability to memorize as much as 70 per cent. In describing his methods of work, Helmholtz said that slight indulgence in alcohol dispelled his best ideas.

### Moral Deterioration produced by Alcohol

[Professor H. Newell Martin]

" One result of a single dose of alcohol is that the control of the will over the actions and emotions is temporarily enfeebled; the slightly tipsy man laughs and talks loudly, says and does rash things, is enraged or delighted without due cause. If the amount of alcohol be increased, further diminution of will power is indicated by loss of control over the muscles. Excessive habitual use of alcohol results in permanent over-excitement of the emotional nature, and enfeeblement of the will; the man's highly emotional state exposes him to special temptations, to excesses of all kinds, and his weakened will decreases the power of resistance; the final outcome is a degraded moral condition. He who was prompt in the performance of duty begins to shirk that which is irksome, energy gives place to indifference, truthfulness to lying, integrity to dishonesty; for even with the best intentions in making promises or pledges there is no strength of will to keep

them. In forfeiting the respect of others, respect for self is lost and character is overthrown. Meanwhile the passion for drink grows absorbing; no sacrifice is too costly which secures it. Swift and swifter is now the downward progress. A mere sot, the man becomes regardless of every duty, and even incapacitated for any which momentary shame may make him desire to perform.

"For such a one there is but one hope — confinement in an asylum, where, if not too late, the diseased craving for drink may be gradually overcome, the prostrated will regain its ascendency, and the *man* at last gain the victory over the *brute*."

## Narcotics

**Definitions of Narcotics.** — Gould's *Dictionary of Medicine*, one of the very best authorities, thus defines narcotic: "A drug that produces *narcosis*," and narcosis as "the deadening of pain, or the production of incomplete or complete anesthesia by the use of narcotic agents, such as the use of anesthetics, opium, and other drugs." It is common, however, to treat of chloroform, ether, chloral hydrate, etc., in a group by themselves under the designation Anesthetics.

*The Century Dictionary* thus defines narcotic: "A substance which directly induces sleep, allaying sensibility and blunting the senses, and which, in large quantities, produces narcotism or complete insensibility. Opium, *Cannabis indica*, hyoscyamus, stramonium, and belladonna are the chief narcotics, of which opium is the most typical. Direct narcotics . . . either produce some specific effect upon the cerebral gray matter, or have a very decided action on the blood supply of the brain."

Some authorities class alcohol with the narcotics.

**Opium.** — Opium is the dried juice of the head, or capsule, of a species of poppy. Incisions are made in the partially ripened heads; the milky juice exudes; after about twenty-four hours the partially dried and thickened material is scraped off with a dull knife. As gathered it is a reddish brown, sticky substance of peculiar odor. It is soluble in water, alcohol, and dilute acids, to all of which it gives a deep brown color. It is a very complex substance, but the chief constituent is *morphia*, or morphine, to which the properties of opium are due. "Opium was known to the Greeks, but was not much used before the seventeenth century; at present it is the most important of all medicines, and its applications the most multifarious. . . . Its habitual use is disastrous and difficult to break up. It is classed as a stimulant narcotic, acting almost exclusively on the central nervous system when taken internally; in large quantities it is a powerful narcotic poison, resulting in a coma characterized by great contraction of the pupils, insensibility, and death." — *Century Dictionary.*

**Cocaine.** — Cocaine is an alkaloid extract of a shrub native to the Andes. It is much used by the natives for sustenance during long journeys. Large doses have a narcotic effect and cause hallucinations. Its long-continued use is followed by insomnia, decay of moral and intellectual power, emaciation, and death. Locally, it is a powerful anesthetic in a limited area of surface, hence it is used for minor surgical operations.

**Chloral Hydrate.** — This drug is frequently, but incorrectly, called chloral. It is a powerful hypnotic, antispasmodic, and depressant to the brain and spinal nerve centers, and, to a limited extent, is an anesthetic. No

drugs of this class should be used except under the advice of a physician.

**Chloroform.** — In a similar way this anesthetic, whose discovery is one of the greatest importance in modern surgery, is abused for the sake of its effect on the system, and the hold such a habit gets over the user is similar to that of the alcohol or opium habit. Its use by an inexperienced person is fatal.

**Other Narcotics.** — The list of narcotics might be enlarged: the Indian hemp, so much sold in Calcutta and from which Arabians make the special preparation, hashish; belladonna, a preparation made from the deadly nightshade; heroin, one of the newer preparations from opium; antikamnia, one of the much advertised "headache powders." Though the effect of each varies, the habit, if persisted in, is dangerous.

**The Action of Narcotics.** — They all act on the nervous system. The use of many of them is begun during illness, when they are administered to relieve pain, as in neuralgia. The habit, once formed, is hard to break. Others, having heard of the effects of these drugs, are unwise enough to experiment on themselves. Only the confessions of such victims, and the degrading effects on character, show how powerful is the sway which this class of drugs gains over those who yield to their influence. Let no one flatter himself that he has a strong will and can control himself. The history of their use is ever the same. They enslave. They destroy. Anything which exerts so powerful an influence should be put in the hands of a competent physician — and only in his hands.

**Tobacco and Nicotine.** — The use of tobacco is needless. Man gets along well enough without it. It is especially

injurious to boys. Another very selfish feature is that so many men do not seem to consider the fact that the air is public property, and they have no right to fill the air with any gas or smoke that is offensive to others. The active material in tobacco is a substance called *nicotine*. It is a violent poison. A drop of it in concentrated form placed on the tongue will kill a cat or a dog as quickly as chloroform.

**Cigarette Smoking.** — It seems to be clearly proved that cigarette smoking is very injurious, especially to boys. Some of the cigarettes are said to be steeped in preparations of opium, so that the use of cigarettes is often subjecting the user, not only to the tyranny of tobacco, but to that of opium as well. If boys knew that the cigarette habit leads to mental inefficiency, debility, and perhaps to worse habits, possibly to insanity, or death, would they not shun it?

**General Effects of Tobacco on the System.** — Tobacco usually diminishes the natural appetite for food and interferes with digestion. It affects the stomach and the lungs and may induce a craving for alcoholic drink. The eyes are frequently affected. Smoking often irritates the mouth and throat sufficiently to make the voice husky. The heart also is very frequently affected, the beat becoming unsteady. The muscles are in some cases weakened and affected by trembling.

**The Moral Effect.** — It is an unchallenged claim that the greatest thing an education — the being properly brought up to mature life — can give, is character. And a fundamental factor in character is proper moral development.

It is wrong to go to excess in food as well as in drink — wrong both to ourselves and to those whom we make uncom-

fortable by our gluttony. Morally, we are bound to obey the laws of health and to regard the health and happiness of others. We cannot live in this world alone, and our community life entails on us the civic duty of living in conformity with the good of all. Alcohol liquors, tobacco, and other narcotics are harmful to ourselves and offensive to others.

**Call to the Younger Generation.** — Although these truths about the harmful effects of alcohol and narcotics should be well learned and understood by young people, it would be unwise for them to try to reform their elders, and disrespectful in them to take older people to task for habits which they formed long ago — perhaps without warning as to consequences. Perhaps they might be glad to lay aside the habits if they had the will power to do so.

Boys may think smoking is manly; they wish to do as others do. It is not manly to imitate any one. Do not do something simply because some one else does it. To do this is to be a slave, to be led. And one bad feature of the tobacco habit is that one makes himself a slave to the weed. For, like other narcotics, it has a powerful influence on the nervous system, and the habit, once formed, is hard to break. It is never quit by "tapering off."

How many men have been heard to say, "I wish I had never formed the habit." Has any one in middle or later life ever been heard to say, "I wish I had formed this habit"?

We should pity the enslaved inebriate, or weep, rather than laugh, at his deranged conduct. If boys who have the moral stamina would, for themselves, say, "I won't," and to other boys, "Don't taste liquor or tobacco," they would be the advance guard of an army that would free the country from the evils of intemperance.

Though girls are usually in less danger from this temptation than boys, the part they can take in reform is of equal importance. They must count by their influence. Woman should sway or move man to good, upright, moral living. It is her duty, her privilege. The girls are the women of the future generation, and should use their influence to help the boys avoid narcotics and liquor.

### QUESTIONS FOR REVIEW

1. What is alcoholic fermentation?
2. What are the proofs that the yeast-plant causes this process?
3. In the fermentation of sweet liquids, what two substances are produced? Which of these makes bread rise?
4. How does the yeast plant accomplish this?
5. Are there other kinds of fermentation? Name, and give the cause, in each case.
6. What are the similarities of these to alcoholic fermentation? What the differences?
7. Give the principle and the process in wine-making.
8. What per cent of alcohol stops fermentation?
9. What are the objections to wine-drinking? To the use of hard cider?
10. How and from what is vinegar made?
11. What is the danger in the so-called " temperance drinks "?
12. How is the sugar formed from barley in making beer?
13. What is the principle employed in distillation? Describe the process.
14. What per cent of alcohol is usual in first distillation? What is meant by " rectified spirits "?
15. What kinds of alcohol are there? What are the *legitimate* uses of each?
16. What are the effects and dangers of small quantities of alcohol?
17. How will the habitual use of alcohol affect character? Why?
18. Compare the apparent and the real effects of alcohol " in moderation."

19. Why has alcohol an especial effect on the nervous tissue?

20. What effect has alcohol on the arterioles of the skin, and on the organs?

21. What is the testimony concerning the habitual use of alcohol (*a*) in the army; (*b*) during prolonged exertion, mountain climbing, etc.; (*c*) in the tropics; (*d*) in business?

22. Can alcohol build up the tissues of the body?

23. What organs are especially liable to ill effects from the use of alcohol?

24. How does the habitual use of alcoholic liquors affect the user's chances (*a*) in case of operation or exposure to disease; (*b*) in case of accident; (*c*) in effect on his children; (*d*) on the community — his neighbors?

25. What is the popular misconception of the beneficial effect of alcohol on mental operations? Show that it is a misconception.

26. Define a narcotic. How near does alcohol come to this meaning?

27. Name some of the narcotics.

28. What is the dangerous effect of each?

29. Should chloroform ever be used by the inexperienced? Why not?

30. How has the violent narcotic effect of nicotine been shown?

31. What are the general objections to the use of tobacco (*a*) from a physiological point of view? (*b*) from a social point of view?

32. Why are cigarettes especially harmful?

33. What is the moral side of the use of alcohol?

## EXERCISES

*Alcoholic Fermentation.* — 1. Let each pupil clean and fill a wide-mouth bottle one-half full of a dilute sugar solution, or grape juice, or molasses and water, starch and water, or flour and water, — each different, — and put the bottle in a warm place. A second similar set is to have yeast added to the contents of each bottle. Two specimens with sugar solution and yeast, or molasses and yeast, are to be taken home by a pupil and placed in a refrigerator. Two others are to be heated in boiling water, in a double boiler, for fifteen minutes. When specimens begin to show results, all should be compared for

two or three days, as to (*a*) appearance — clear or cloudy; (*b*) gas bubbles, or none; (*c*) odor. Has any change in odor taken place? How do the specimens kept in the refrigerator compare with those in the warm room? — with those whose contents have been heated to boiling?

2. To learn the kind of gas given off in fermentation: Into a quart fruit jar is put a half teacupful of molasses and a cup of warm water. A little yeast is added and the jar is covered and set in a warm place. After bubbles have been rising from the liquid for half a day, a *lighted* splinter of wood is carefully inserted. If the experiment is successful, the kind of gas given off by alcoholic fermentation may be further proved by carefully pouring the gas from the jar into a tumbler with clear limewater in the bottom, closing the tumbler and shaking it.[1] What effect does the gas have on limewater? From Ex. E 3, *a* on Respiration, you can now tell the gas present.

3. To detect alcohol formed in fermentation: *A*. (*a*) A test for alcohol is to add a few drops of alcohol to water in a tumbler, then a few drops of iodine and a small quantity of a solution of caustic potash or soda. The peculiar odor of iodoform is very noticeable. (*b*) Try, in the same way, a tablespoonful of the liquid from any of the fermented specimens used in Ex. 1.

*B*. Produce vigorous fermentation with molasses, water, and yeast in a glass flask of 250 c.c. capacity. Close the flask with a stopper through which passes a glass delivery tube drawn out to a fine opening. When the contents of the flask are heated to near boiling, the alcohol vapor driven off can be lighted at the narrow opening of the tube and will burn for some time.

4. The use of yeast in bread-making: A tumbler or other small glass vessel is filled two-thirds full of dough, a thick mixture of flour, water, yeast, with a pinch of sugar. This is set in a warm place for a few hours, when it should be observed. Has it "risen"? What change (*a*) in bulk? (*b*) in appearance? (*c*) in odor? What has caused the rising? (It can be seen through the glass.)

[1] The student is supposed to have learned the test for carbon dioxide in exercise on Respiration. If he has not seen that test, it should now be done as a control.

# CHAPTER XVI

## GENERAL HYGIENE AND SANITATION

**The Application of Physiology.** — It has been said that a thorough knowledge of higher physiology will enable a physician to diagnose many ailments that come to his attention. A briefer course should lead *students* to an avoidance of many of the ills that befall those who are ignorant of reasons for hygienic practices.

Some common ailments and diseases of the body have been mentioned in connection with the systems of organs affected. Yet the general facts of the causes and the conditions favoring the spread of disease need to be studied more fully in order to enable us to exercise proper preventive measures.

### GENERAL CONDITIONS LEADING TO DISEASE

**Colds.** — It is common physiological knowledge that prolonged chilling of the skin from exposure to low temperature, or from wet clothing, drives the blood inward, causing congestion of some of the internal organs. Colds may lead to pneumonia, acute gastritis, and other inflammatory diseases; or, where the chilling is not so severe but oft repeated, it may lead to chronic inflamed condition of the mucous membranes of the internal organs, called catarrh.

**Overwork.** — While exercise of all the functions of the body is necessary in either our vocation or our recreation,

if we make this such a burden to the organs that they become exhausted, a chronic ailing condition may result. An overworked heart may be the cause of death.

**Tobacco and Liquor; Overeating.**—Constant overeating or the eating of improper food, the excessive drinking of alcoholic liquors, the use of tobacco and drugs, all lead to a diseased condition of the organs. Even the moderate but habitual use of tobacco and alcohol weakens the tissues to such an extent that the organs are more easily subject to disease.

In the case of a distinguished patient who had a bullet wound in his abdomen, the attending surgeon is reported to have said that the tissues succumbed to gangrene so easily because of the habitual and excessive use of tobacco. In surgical operations, the user of tobacco or alcoholic drinks is similarly handicapped in his recovery, while the man of good habits often surpasses the expectations of his physician. Live well and you will not need to recover well.

It is especially true of ailments of the organs that ordinary ailments become diseases when the abnormal condition of the organ is continued. Such a condition is then called chronic, *e.g.*, chronic catarrh of the stomach. Thus we have chronic and acute diseases. Besides these there are the more dangerous "infectious diseases."

**Contagious and Infectious Diseases.** — While many ailments and some serious organic diseases may by proper living be avoided, there are diseases that we cannot avoid when coming in contact with those who have them, or with certain carriers of such diseases. Infectious diseases are so called because they are due to outside infection, formerly supposed to be in the air or on the bodies of those stricken with the disease; *e.g.*, diphtheria, smallpox, malaria, measles.

In such cases where contact or touching was known to give the disease it was called *contagious*, but where it was not so evident how the disease was transmitted, as in diphtheria and malaria, it was called *infectious*.

Then by man's ingenious ways of applying personal and public hygiene, it was made possible to escape these infectious diseases: 1st, by isolating those stricken with such a disease; 2d, by destroying the carriers of disease, *e.g.*, flies, fleas, mosquitoes, etc., or preventing their approach to human beings.

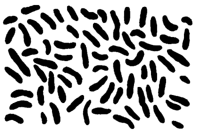
Through the experiments of the great French biologist, Louis Pasteur (see frontispiece), and the later researches of the German bacteriologist, Prof. Robert Koch, it was learned that the infection in all diseases that can be transmitted from man to man, either directly or indirectly, is brought about by the germs which cause the disease.

**Germs are either Plants or Animals.** — It is valuable to know: 1st, that there are myriads of germs in the world, only a few of which are parasitic, *i.e.*, cause disease by living in the bodies of other living animals or plants; 2d, that all living things are classified, *i.e.*, put into the animal or plant kingdom, even though they do not at all correspond to our notion of what an animal or a plant looks like. Scientists do not tell from appearances but from the physiological activities of an organism whether it is plant or animal.

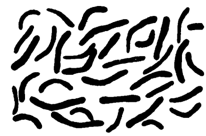
There are two great classes of germs: 1st, germs that are classed among plants and are called *bacteria* — the smallest and simplest of all living things; 2d, those that are classed among animals, and are called *protozoans* — the name meaning the first or simplest class of animals.

**How we become Infected.** — It is the current opinion that once exposed to an infectious disease one is sure to " come

down " with it. Germs ordinarily escape detection because they are not perceivable by unaided senses; *i.e.*, we cannot feel, taste, smell, or even see them, unless we use a powerful microscope. Therefore they are easily swallowed with our food, or taken in with the air we breathe. It is because



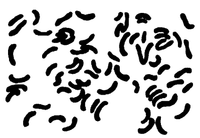
Bacillus of Diphtheria (× 1000)



Bacillus of Tuberculosis (× 1000)

Bacillus of Typhoid Fever (× 1200)

Typhoid Bacillus, showing flagella



Bacillus (Spirillum) of Asiatic Cholera

Bacillus of Hog Cholera (× 1000)

Fig. 106.—Types of bacilli, showing morphologic characters and arrangement

we cannot see the germs that we cannot ward them off by any except precautionary measures. Many clean people are not conscious of the unseen dirt they breathe and swallow.

If a person stricken with an infectious disease developed only a few germs, we should probably not easily take the disease, but we must remember that the number of germs produced during the course of a disease is not hundreds or thousands, but probably millions, of the special kind that

causes the disease.[1] Being so numerous they may be left on everything that touches or is near the body of the patient — food, clothing, the air, door knobs, books, playthings.

**How to ward off Contagious Diseases.** — A good general condition of the body helps greatly to ward off diseases of this nature. A cheerful condition of mind and a sound body should be cultivated. In times of widespread contagious diseases, if one is terrified into the belief that he is going to have the disease, he is more likely to take it, because of lowered vitality. Avoidance of unnecessary contact with sick people and avoidance of crowds will prevent infection to a certain extent.

Thorough cleanliness, plenty of direct sunshine, care in diet, and the keeping of the body in good tone — all these reduce the chances of "taking" contagious diseases.

**The Germ Theory of Disease.** — Pasteur paved the way to the knowledge that microscopic germs cause diseases, that the infection can be given to others, and that a diluted infection if inoculated in an animal may give freedom from the disease, *i.e.*, "immunity." Dr. Koch discovered the bacteria that cause cholera and those that cause tuberculosis, and on these and other discoveries he formulated the "germ theory of infectious diseases" as follows: —

1. That each infectious disease is caused by a special kind of germ which is found in the fluids or tissues of the body affected; that the poisonous excretions of the germs cause the injuries to the body and the resulting symptoms of the disease.

For instance, in tuberculosis of the lungs the specific germ is the tubercle bacillus, a rod-shaped bacterium. It forms swellings or

[1] Some kinds of germs develop a new generation every 20 minutes. How many would there be in 6 hours?

nodules in the lung tissue; the tissue breaks down and the lungs waste away. The poisons — toxins — are carried by the blood to all parts of the body; fever, weakness, night sweats, indigestion, hectic cough, and finally suffocation from lack of lung surface, all follow in due time.

2. The special germs of a disease, when obtained free from other germs, *i.e.*, in pure culture, and introduced into another body in a fit condition to take the disease, again produce the disease in the new host, going through the same destructive cycle as before.

3. The same kind of germs can be found in each successive case of the disease or in an animal inoculated with pure culture germs of the disease.

**Immunity and Antitoxins.** — In the chapter on the skin it was stated that vaccination for smallpox produced immunity for five years. In case of typhoid inoculation it was stated to be three years (page 88). Temporary immunity or cure is obtained in the case of diphtheria in a unique way. Instead of inoculating the patient with mild virus to develop antigens (page 87), horses are inoculated, and after the antigens are formed, some of the blood of the horse is drawn off and antitoxin is prepared from the serum. Whenever a child has been exposed to diphtheria, the antitoxin is injected and this helps nature to overcome the diphtheria poison.

*Courtesy of Dr. Schamberg*

Fig. 107. — Appearance of normal vaccination on the seventh day

If a person is bitten by a mad dog or cat, he should go to the nearest Pasteur Institute and be inoculated with

weakened germs of the disease. The blood then develops antigens, killing the germs of rabies (preliminary treatment of the wound is described in Chapter XVII).

## Hygiene and Sanitation of Communicable Diseases

**Consumption or Tuberculosis.** — Forms of this disease may affect various organs of the body, but the most prevalent form, causing tuberculosis in the lungs, is the one ordinarily meant, and this form gives it the name. Pulmonary tuberculosis is most common between the ages of fifteen and forty-five. A consumptive expectorates on the pavement. In this sputum are probably hundreds, if not thousands, of germs known as bacilli (*Bacillus tuberculosis*). They are alive. Now, so long as they remain on the pavement they do no harm. The sputum dries. But the bacilli are not killed by drying. With other dry material from the pavement they form part of the common dust. Any one of us may breathe some of this kind of matter any day, for there are persons afflicted with this dreaded disease in every community. Our weakened lungs furnish the very best soil for the germs.

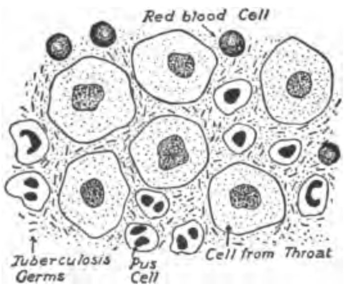



Fig. 108. — Tuberculosis germs

Expectoration, showing a great number of tuberculosis germs, which spread the disease if not destroyed.

**How to avoid Consumption.** — Of course, all such material known to be highly dangerous ought to be destroyed. If those suffering from such diseases were careful to burn all such matter, most of the germs of this disease would be killed. But so long as people spit upon floors and pavements it

will be difficult to prevent the spread of such germ diseases. In hospitals and in private houses where there is intelligence on these subjects such matters are now looked after with the greatest care. It is encouraging to note the awakening of the public to the significance of the teachings of modern science on this subject, as shown by the fact that many of the railroad and street car companies prohibit spitting on the floors of cars, not merely because it is uncleanly, but on the express ground that it is a means of spreading infectious diseases.

Fig. 109. — Showing an inexpensive out-of-door sleeping porch with tent for protection in stormy weather. Cost, about $ 25

**Outdoor Treatment of Consumption.** — Lung diseases usually accompany close confinement, but are rare with those who live in the open air. Formerly many consumptives were sent to Florida, Colorado, the Adirondacks, and the mountains of North Carolina. Whatever advantages there may be in mild climate, dry air, sunshine, etc., there is little doubt that the chief benefit came from the fact that the patient spent much of his time in the open air, and, when indoors, had the windows open day and night.

It is not now considered necessary to send a consumptive far from home. The main thing is to *send him out of doors.* He may sleep on a porch, secluded and protected by canvas curtains. In Massachusetts, Pennsylvania, Illinois, Michi-

gan, and other states, there are colonies of consumptives living in sanatoria, tents, or cabins. Often the cabins are entirely open on one side. When necessary they are warmed by stoves. Suitably clothed, the patient may be comfortable in any season or weather. In this outdoor treatment little medicine is used, but great care is taken to supply *ample and suitable food*. This method has cured a large per cent of the patients. Of all the remedies for lung trouble, the best, the cheapest, and the most common, is fresh air. Yet many persons dread " exposure," but the more closely they remain housed, the more sensitive they become to cold and rough weather. It is a rare thing to " take cold " in camp. The increased vigor with which one returns from a camping trip is partly due to breathing fresh air twenty-four hours a day.

An open-air life, abundant nutritious food, and freedom from anxiety are probably the best restoratives for incipient consumption.

**Lung Diseases.** — Statistics seem to show that one-seventh of the deaths among the civilized races is due to lung diseases. The best authorities are now agreed that consumption is not hereditary. But it appears that there may be inherited a tendency to this disease, so that, if exposed, such persons are more likely to contract the disease than those not so predisposed.

Probably anything that lowers the general vitality makes the system more ready to succumb to any of these contagious diseases. We have all noticed what a difference there is among individuals in the readiness with which they " catch " contagious diseases.

**Destruction of Germs by Colorless Corpuscles.** — It is well to recall in this connection that the colorless blood

corpuscles may take germs of disease into their substance, and destroy or change them so that the disease is warded off. In other words, they may be compared to a cat that catches and eats the mice which invade a house.

**The Educational Campaign.** — The educational exhibits for instructing the public in the prevention of tuberculosis not infrequently have a clock ticking about once in three minutes to indicate the death rate from tuberculosis in the United States.

In many of the larger cities there are now "open air" schools for the tuberculous children of the city. Here they have all their meals and one hour's sleep at noon.

The great lesson to be learned for the future is that the educational campaign of prevention should be pushed ahead of the campaign for hospitals and sanatoria, since it will make the latter less necessary.

**Pneumonia.** — Pneumonia is said to be caused by several kinds of germs.[1] The germs are spread by the discharges from the throat, lungs, and nose, and being received through the mouth, they lodge in the throat, where they may remain until one takes a severe cold, then pneumonia develops. While not ordinarily very contagious, at times a more vigorous generation of germs develops, and slight colds weaken the body to give these germs the upper hand. Toward the end of the winter, germs are at their best, and people are more susceptible to colds, therefore there is then more pneumonia.

NOTE. — It is a striking fact that in various diseases at times the germs seem more poisonous and cause death quickly. Illustrations are: virulent pneumonia, "galloping" consumption, black smallpox.

[1] One especially identified with it is the *Pneumococcus*, a microscopic globular germ.

But their virulent condition quickly leading to fatal termination is not what is commonly called "epidemic." This term is used by physicians when a large number of people are sick at the same time from the same disease; *e.g.*, an epidemic of grip, pneumonia, or typhoid fever. Historical names, as "pestilence" and "plague," meant about the same.

Pneumonia is dangerous, especially so to young children and very old people and to those who are fleshy. Here there is an advantage in being lean. The usual methods of avoidance of predisposing causes, and, when afflicted, careful disinfection of the discharges from the mouth and nose are to be practiced.

**Typhoid Fever.** — After the discussion of typhoid fever under ailments of the alimentary canal, page 73, there remains to be urged that this disease (as well as tuberculosis) could be wholly eliminated through proper personal and domestic hygiene. Since the germs leave the body of the patient only through the dejecta and the urine, spread of the disease may be positively prevented: 1st, by using toilet paper freshly soaked in a disinfecting solution each time the body is rid of its wastes; 2d, by carefully washing the hands of nurse and patient, after rubbing the fingers with a disinfectant[1]; 3d, by disinfecting the dejecta and the urine before they are removed from the room; 4th, by barring flies and other insects from the room. When the above precautions have been rigorously carried out, even for several weeks after recovery, there will be no danger of water, milk, or sewage contamination. Camping and outing parties should exercise the greatest caution in re-

[1] Experiments have shown that *rubbing* of soiled fingers with a disinfectant is necessary to remove and kill germs. Typhoid germs are not killed by freezing, therefore ice should be used only to cool the outside of the drinking vessel. For disinfectants see Appendix, page 363.

gard to drinking any but the best well water from deep wells, ten feet deep or more. If too far from such wells, the water should be boiled.

There are cases of "walking typhoid," persons who may carry the germs long after the illness, or who are not even confined by the mild attack. In going about their duties as housemaids or dairymen they spread the disease by their untidy habits.

**Malaria.** — Malaria is a good illustration of a disease that is infectious but not contagious. There is no danger of taking the disease from contact with others. The in-

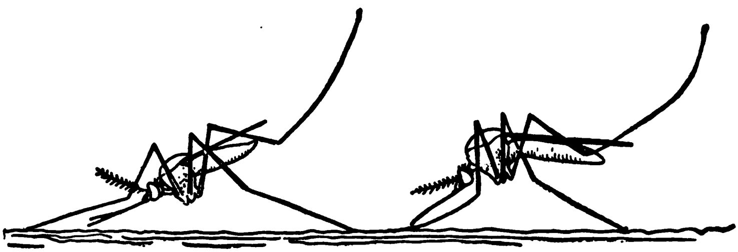


Fig. 110. — Mosquitoes

On the left the mosquito that carries malaria; on the right the harmless mosquito. In resting position

fection, a protozoan germ, is inoculated in the blood by the bite of a kind of mosquito.[1] In the body of the mosquito the germs are developed to a stage in which they can be given to a human being. The mosquito and the human being are called the "hosts" in this remarkable life cycle of the malaria parasites. We can see now why malaria was formerly almost epidemic in swampy regions where the *Anopheles* occurs. It is some years since these facts were discovered, and the people in such regions have kept

[1] The *Anopheles* mosquito stands more nearly on its head in biting than does the common mosquito. The latter cannot transmit malaria.

carefully screened from mosquitoes, thus avoiding the infection. Malaria patients were also carefully screened from the insects that might not yet be infected. There was no further spread of the disease. Thus we see again that there can be no infectious disease without its specific germ, though the carriers may be present.

*Yellow fever* is all but proved to be identical with malaria in the manner of infection, the insect host being another kind of mosquito, *Stegomyia*. The last southern epidemic of this scourge was successfully put down by fighting the mosquitoes.

**Bubonic Plague.** — The bubonic plague (*black death*) was a terror for centuries until the discovery of the infection by the bite of fleas that are carried about by rats. These and other rodents are the original plague victims. Through their death from plague the infected fleas drop off and later bite human beings and the plague is thus transmitted to man, but not commonly from man to man. The plague epidemic in California in 1903 was stopped by the destruction of rats; the same method had been used in the Philippine Islands a few years before.

## Community Hygiene

**Isolation and Quarantine.** — Other infectious diseases, like smallpox, diphtheria, scarlet fever, measles, and whooping cough, are less controllable by personal hygiene. They are so quickly spread in a community that a health officer must be notified. He then placards the house and sees that the patient is properly isolated. The best room in which to care for a sick person is one not connected with other rooms. All things that cannot be readily disinfected, *e.g.*, carpets, draperies, etc., should be removed from the

sick-room. This does not mean that the room should not be cheery. (For more details about the sick-room see Chapter XVII.) Isolation means that *all* other members of the family except the attendant must be kept out of the sick-room. And quarantining, placarding the house with the name of the disease, means that *no one* excepting health officers, physicians, and nurses is allowed to enter or leave the house. The quarantine may be raised after the recovery of the patient and as soon as the health officer is sure that no other member of the family will be ill of the same disease.

**Disinfection; Fumigation.**—As soon as the room has been vacated, everything must be disinfected. This is done by fumigation. For this purpose the room is closed as tightly as possible by stuffing strips of cloth or rags into all cracks and small openings, after closing all windows. The health officer then generates a disinfecting gas, the fumes of which are supposed to penetrate everything and to kill all germs. (See Appendix, Formaline.) No one may enter the room, nor may anything living, like plants or pets, be left in the room, as the gas would kill them. After eight or twelve hours the room is opened, from the outside if possible, and aired. Then all remaining articles had better be washed with liquid disinfectant, and the linen and articles of clothing worn by the patient should be put into a receptacle with water enough to boil them. If this cannot be done, they should be soaked in a disinfecting liquid before being sent to the laundry.

**Public-spirited Support of Quarantine Demanded.**—Although evading the quarantine ordinance in cities is punishable, yet some willful people try to violate it. If they merely endangered their own lives the matter would

not be so serious, but they may be spreading broadcast a dangerous disease entailing much loss of life. We should not only obey when within the quarantined limits, but if exposed, should report to a physician or health officer for observation until the danger is past. Likewise we should submit to precautionary measures such as vaccination, or, if one has fear of this harmless procedure, at least conscientiously remain away from other people until the danger is past.

**Disease Carriers.** — Familiarity with disease carriers will help us to be on our guard against them. We already know that a special kind of mosquito called the *Anopheles* carries the malaria germs. Flies may deposit typhoid and consumption germs on our food. Several insects in tropical countries also inject deadly germs with their blood-sucking probosces. Bubonic plague, which in the fourteenth century swept away half the population of England, was of frequent epidemic occurrence in the Philippine Islands until occupied by Americans. Our scientists confirmed the rat-flea transmission theory of the plague germs. For all cases the general rule must be: first, destruction of the disease carriers everywhere; second, prevention of breeding; third, guarding people against the carriers by preventing their entrance to human habitations.

## Ventilation and Heating

**A Lack of Effective Systems of Ventilation.** — The houses where the largest portion of our time may be spent should be properly ventilated, otherwise our health soon becomes impaired. Lung diseases are rare in the regions where the windows and doors may be kept open most of the days of the year. It is from shutting ourselves in so closely that

we suffer. This is especially true where many people are housed in a comparatively small space, as in many public buildings. But in our private dwellings, even when the owners are amply able to secure the most sanatory appliances, defective apparatus is often put in. *Any system that does not provide for a constant renewal of the air is defective.*

**The General Principle of Ventilation.** — Of the forces that operate *to renew the air* two are natural, diffusion and the wind; and two are artificial, warm-air shafts and fan systems. *Movement of air is the aim in all systems of ventilation.*

**Diffusion.** — Gases tend to mix. We know that if a bottle containing an odorous substance be opened in a room where there are no air currents the odor tends to spread equally through the room. So if a person is in one corner of a large room, where there are no inlets or outlets, and no currents, as he uses the oxygen immediately around him, the oxygen farther away will diffuse toward him so that he will continue to get oxygen until the amount that is in the room is nearly exhausted. So, too, the gases that he breathes out will not remain confined to the space directly about him, but will spread evenly throughout the room. The same takes place in the open air, without wind. So, then, if the windows and doors are open, the air of the room will, by diffusion, be renewed.

**Wind.** — Motion of the air renews it faster than mere diffusion. Strong wind forces its way through the cracks around windows, and when windows are open on opposite sides of a room there is usually enough breeze to renew the air. But during the greater part of the year this cannot be done.

**Artificial Renewal of the Air.** — The renewal of the air in most cases depends on the fact that heated air rises.

Heat expands air. It is then lighter, bulk for bulk, than cooler air. The heavier surrounding air presses the lighter air upward. If there are outlets above and below, the heavier, colder air will press in at any opening left below, and push the lighter, warmer air out above.

**Ventilating Flues around a Chimney.** — If small ventilating flues could be built around the flue of the main heating apparatus, and connected with the various rooms of the house, air could be drawn from these rooms by ascending currents created by the heat of the central smoke flue or chimney. Such flues surrounding chimneys would have the added advantage of protecting the house from fire through the too common "defective flue."

**Foul-air Shafts and Fans.** — Although in private dwellings heated by furnaces there is no special provision for the escape of foul air, there is ordinarily sufficient renewal of the air. But in public buildings there should be escape flues for foul air.

Frequently a large foul-air shaft is built in some central part of the building, and a small stove placed in it to create a sufficient upward current. In many public buildings the currents created by heat are insufficient to move the air properly. Fans are used, which force properly heated air into the room.

**Grates.** — Grates will aid largely in renewing the air. Although in themselves they merely have provision for sending radiant heat out into the room and much air up the chimney, yet, without any special provision for inlet of air to the room, they draw air in through every crack and crevice. It would probably be better to have special ducts for the admission of air, which could be suitably warmed while on its way into the room, and to make the

doors shut snugly, and to have double windows, as then both the admission of fresh air and the regulation of heat would be better secured. But it is a serious question whether, with all our modern appliances, conveniences, and luxuries, we have better air in our houses, and take cold less frequently, than our ancestors did who depended more on the fireplace, even if they "roasted on one side while they froze on the other." Fireplaces are expensive as mere heaters, but they are excellent as ventilators.

**The Common Stove.** — We very well know that there are currents of heated air rising above the stove when the fire is burning. Children make whirligigs and various toys to place in these up-currents above stoves. Air is, at the same time, flowing toward the stove along the floor and lower part of the room. Cold air can usually be detected entering around the windows and doors. This presses downward and toward the source of heat. The stove does not do much to renew the air in the room except in this general way; some heated air escapes at openings in the upper part of the room, and some is passed out through the stove, taken in as a draft. But in the main, the action of the heat of the stove is to make a current of warm air rise upward from it; this current passes along the ceiling to the more distant corners of the room, then descends, joining the cold air, and repeating the round.

**A Stove and Jacket.** — In some cases a jacket is placed around the stove, and a duct from the outer air connects with the lower part of the space inside of the jacket and outside of the stove. Then as the air heated by the stove rises, fresh air is drawn in from outside to be warmed. In this case the direct heat from the stove is shut off from

the room. Heat radiates in straight lines. When one holds out his hands beside a stove the heat that he receives is radiant heat. Most of the heat from a grate is radiant heat. But in a jacketed stove the heating by air currents is called heating by convection.

**The Furnace.** — A furnace is practically a jacketed stove, almost always placed in a basement. Furnaces have this valuable feature — they are all the time sending fresh air into a room, provided the air shaft is open to the outside air. In some houses there is also an air shaft from the hall to supply air to be heated when the weather is very cold. This method of getting air to heat is likely to be unsanatory, as sleeping rooms are also frequently opened into the hall on cold nights. A still more unsanatory practice is found in hot air furnaces sometimes installed with a return pipe from each room, thus heating the same air over and over. With only an outside air shaft, the hot-air furnace is the better ventilator. The air can also be kept more moist than with the use of steam heat.

In houses heated by furnaces, steam, or hot water, the floor is likely to be warmer from the escape of heat from the heater itself, and from pipes or air ducts under the floor.

**Indirect Heating.** — The furnace is an example of indirect heating, *i.e.*, heated air sent into the room from a common source. Another method of indirect heating is where coils of steam or hot-water pipes are placed in air shafts which lead up to the rooms above, and also have ducts to the outside. As the air is heated by the heat of the pipes it rises into the rooms above, and fresh, cold air presses in through the ducts, to be, in turn, heated and sent up. If there is at the same time a proper escape for the foul air, this makes an excellent system.

**Direct Heating.** — In heating by steam or hot water, if the radiators are placed in the room they give direct or radiant heat. This system is called direct heating. In itself it has no provision for renewing the air. It gives direct heat, and produces air currents within the room, but any change in the air is wholly incidental, from escape of heated air in the upper parts of the room and corresponding suction of outside air through such openings as the carpenters have left below.

For this reason the windows should be opened for one half hour to one hour per day in winter weather. It is sometimes claimed that the heat from hot water radiators is less drying than that from steam. This is not due to any escaping moisture from the hot water pipes, as is popularly supposed, but is rather due to the drying effect of the more intense steam heat.

With a grate, in private houses, there is ordinarily no need of other foul-air shaft for any room. But it is very desirable to have at least some "indirect" heat, so that the fresh air introduced will be sufficiently heated.

If the introduction of air is thus provided for, it is then safe to put on double windows and make the cracks around the door very tight. Without any special provision for the renewal of the air these cracks are the means of safety.

In many situations the direct and indirect may be advantageously combined. Where there is a grate in a room, it serves very well as a foul-air shaft, especially when there is a fire in the grate. It is well to have a flue from the grate in the same chimney with that from the furnace smoke flue, as then the heat from the fire will cause a constant updraft in the grate flue, whether there is a fire going in the grate or not.

**Double Windows.** — To understand the service of double or storm windows we must bear in mind two properties of

air. One is that it expands on being heated, and rises, or is pushed above cold air. We can now understand that there is some truth in the statement that with single windows we are heating all out-of-doors. The cold air against the outside of the window-panes is heated and rises, while more cold air takes its place. Another property of air is that it is a poor conductor of heat, receiving heat and holding it but not passing it along, so that where air is confined, as between storm sash and inner sash, we have a protective, non-conducting chamber at each window. It is economy to use double windows and prevent the loss of heat through the glass. So both economy and comfort suggest to us that we reduce as much as possible cracks around doors and windows, use double windows, make vestibules at entrances, and build special ducts by which fresh air may enter, and heat it properly on its way in.

## Dust and Germs

**Sources of Dust.**[1] — One of the disadvantages of a hot-air furnace is that it brings dust into the house with the air. Where soft coal is used to any large extent it is an abundant source of this dust. In summer dust has many sources. The dust that blows into your face, and perhaps into your mouth, may be made of dry soil. Take a dry clod and drop it; it falls quickly to the ground. Pulverize it in your hand before dropping it, and considerable of it floats in the air for some time. Any substance that is easily dried and pulverized may form part of the common dust. The dust

[1] There is in all space what is called cosmic or interplanetary dust. If it were not for the dust in our atmosphere there would be no diffused light — no daylight in a room except the direct rays of the sun.

that you wipe from your eye, or is caught by the mucus of the nasal passages, may, instead of being made of clean soil, be from decayed leaves, wood, grass, etc. Indoors we are constantly making dust by wearing out our clothes. Many of the tiny particles that we see floating in the sunbeams are bits of cotton or woolen fibers. Shake any garment in a beam of light to see how much, and how easily, dust is given off. The worn-off particles of our shoes, books, floors, all contribute to the ever-present dust.

**Sweeping and Dusting.** — So far as possible let us avoid things that make dust. When we sweep a carpet, a considerable share of the dust comes from the carpet itself, especially if the carpet is old. Curtains and tapestries of nearly all sorts not only hold dust, but contribute a good deal to it. Those who write on such subjects recommend hard-wood floors with rugs instead of carpets. The rugs can be taken out of doors and shaken, and the floors wiped with a moist cloth, so that little dust is left floating in the air of the room. Compare this with the condition that holds after the ordinary sweeping of a carpeted room with the common broom. The dust fills the air, only to settle back on the floor and furniture. Then comes the feather duster, and the so-called dusting. Well, it is dusting! It fills the air once more with dust. But do we get rid of it? Wiping off the dust with a moist cloth takes most of it away on the cloth. For those who cannot have hard wood floors a most excellent substitute is oil-cloth or linoleum. Many a well-meaning person will sweep a sick-room with an ordinary broom when the patient may be suffering from lung disease, thoughtless of the fact that a little dust in sight is of much less significance than dust in the air we breathe.

The improved carpet-sweepers are convenient and sana-

tory. Vacuum cleaners are sold that can be operated by hand or by motors, according to one's purse. By the use of a good vacuum cleaner one can remove dust from rugs, floors, furniture, and even from walls and pictures, without spreading it in the air. As indicated above, moist dusting cloths should also be used, but these must be washed out instead of being shaken out of doors as is the common practice. No one likes dust on the floor, but it is far better to have it on the floor than in our lungs.

**The Effect of Dust on the Lungs.** — Dust, so far as it is mere dead, dry matter, not considering it as a poison, is irritating to the lungs and respiratory passages. There is provision, as we have seen, for catching and getting rid of a good deal of it. But still much is taken into the lungs. Examination shows that the lungs have many black specks from particles of carbon, etc., that have become lodged and are of no benefit, to say the least.

**Other Dust Dangers.** — The dust so far considered is dead dust. It has already been pointed out that some disease germs, if not destroyed, may dry up and form part of the dust of the air. They form what has been called "live dust." Besides the disease-producing bacteria, there are others that cause decay and putrefaction of various kinds. Wherever dust collects in damp corners of the house these germs develop and become a menace to health. Air will dry out the damp corners and sunshine will kill the germs. They cause our richer foods to "spoil," milk to turn sour, butter to become rancid, etc.

While these bacteria do not cause disease in the human body, they often make food poisonous. The cases frequently reported of poisoning from eating ice cream, cheese, sausage, etc., are often due to bacteria in these

articles of food. We should, in the first place, be careful to get good, fresh material. In the second place, it should be so kept as to prevent the introduction and development of bacteria in it. Bacteria need heat for their growth. They also need moisture.

**Useful Germs.** — In nature germs of putrefaction are very important, as in the presence of moisture and warmth they cause all waste organic matter to decay or disintegrate and return to the earth, thus enriching the soil. If there were no germs, moisture, or oxygen, dead animals and refuse would accumulate on the surface of the earth until it became uninhabitable. The process of putrefaction is similar to slow combustion, but it could not take place without the help of living germs. This is another instance of oxidation of organic substances, taking place under the influence of living matter at a lower temperature than it otherwise would.[1] (See page 118.)

## Community Sanitation

**Refuse.** — All garbage or other refuse on which flies or rats can feed should be kept in closed cans until removed and destroyed. Horse manure is the breeding place for flies and should be screened against them until it is removed. There should be an annual " alley cleaning campaign " in every city and town, and the alleys should be kept clean. We need to learn a good deal more about avoiding and destroying dust.

Towns and cities need more *sprinkling* to keep the dust down. Much more of the refuse and street sweepings and

[1] Germs are also useful in various commercial processes, such as the making and ripening of all kinds of cheese, in dyeing, etc.

cleanings should be burned. The dust of a house should always be burned, as we know not what germs of disease may be in it. If we *burn it*, we shall surely not have to sweep up that dust again. If we send it out of doors it may come back, and we may have to handle it again and again. Besides, we have no right to inflict it on our neighbors. Fortunately Nature helps periodically in removing dust from the air.

**The Air is washed by Rain or Snow.** — Every one will recall how delightfully refreshing the air is after a rain or a snowstorm. This is not due merely to the fact that the air is cool. It is clean because it has been washed. The rain and snow absorb a considerable amount of the various impure gases that are in the air. But raindrops and snowflakes bring down with them many particles of dust that were floating in the air. Take some of the snow that has fallen in a town. It looks pure in its almost dazzling whiteness. But melt some of it, and you will usually find a decided tinge darkening the water, showing that as the flakes sifted down through the air they caught myriads of particles of dust.

**The Disposal of Garbage and Sewage.** — The most common ways of sewage disposal now practiced in cities of the United States are burning, or dumping in bodies of water. A few cities have constructed large tanks where the garbage is treated by strong chemicals, thus "reducing" it to a harmless product; this product is often used as a fertilizer. In some foreign cities the sewage is used directly to fertilize plats of ground on which vegetables are raised. There is more or less danger of spread of disease in this way. But whether garbage or sewage be buried, or thrown into water, or sent into a cesspool or septic tank, its reduction to harm-

less matter is caused by the omnivorous and ever-present germs.

In the country, and in towns without sewers, the sewage is drained into a cesspool — a loosely-stoned pit, underground — to be gradually leached away. This form of cesspool is very dangerous when there is natural drainage toward the well on the premises, even though it is placed twice the legal distance of 100 feet from the well. The modern water-tight *septic tank* of two chambers, with connecting siphons and an outlet for the clear liquid, makes sewage safe. Practically all State Agricultural Colleges will send directions for constructing such septic tanks for country homes. Here, again, germs that work in the absence of air, the anaërobic bacteria, change the sewage into the clear liquid that may be safely spread out in the soil.

**QUESTIONS FOR REVIEW**

1. How may our knowledge of physiology be applied?
2. Name three prevalent causes leading to a diseased condition of organs.
3. What is the difference between a chronic and an acute disease?
4. What are infectious diseases? Name some.
5. How does a contagious disease differ from an infectious one? How are they alike?
6. What is the cause of infectious diseases?
7. How do scientists tell whether germs are plant or animal-like?
8. Why is it so difficult to avoid infection by disease germs (two reasons)?
9. What four conditions will help ward off contagious diseases?
10. What three points must hold good to prove the theory that germs cause disease?
11. What is meant by "immunity"? by antitoxins?
12. How is consumption ordinarily taken?

13. What precautions may be taken to avoid it?

14. What steps must be taken for its relief or cure in early stages?

15. How are typhoid fever germs taken into the body?

16. How do they leave the body to infect others?

17. How do they get into drinking water and food?

18. In what part of the body are the germs of pneumonia found before the disease?

19. What conditions favor the development of the disease?

20. What are four interesting stages in the life history of the malaria germ?

21. What sanatory measures will eradicate the disease?

22. On what sanatory principle has yellow fever been eliminated in the South?

23. In what ways do rats help to perpetuate the bubonic plague?

24. What are the real carriers of the disease? What sanatory measures are used?

25. What kind of diseases must be especially controlled by the Board of Health?

26. What is meant by "isolation," "disinfection," "fumigation," "quarantine"?

27. What are disease carriers? In what three ways may they be fought?

28. What is the principle underlying all systems of ventilation?

29. Why is it necessary indoors? In what ways (natural, artificial) is it carried out?

30. How may ventilation be combined with heating?

31. What are the relative merits of the hot-air furnace *versus* the steam heater?

32. How must ventilation be secured in "direct heating"?

33. What properties of air explain the benefit of double, or storm, windows?

34. What care should be taken about ventilating when they are closed?

35. What are several sources of ordinary dust? what the sources of "live dust"?

36. What effect will live dust have on refuse? on our health? Why?

37. What are three cardinal points in permanently removing dust?

38. How may germs be useful? What three conditions are necessary for their growth?

39. What is Nature's way of laying dust? Why should streets be sprinkled?

40. In what two ways may garbage be treated to utilize it?

41. How should garbage and other refuse be stored until taken away? Why?

42. What is the ordinary treatment of sewage in cities? What in the country?

43. What is the safest way of disposing of sewage in villages and in the country?

44. What organisms convert the sewage in the septic tank into liquid?

## EXERCISES

NOTE. — It is the object of the following exercises to find the sources of germs (bacteria) that harm and benefit man in some ways, to learn conditions favoring their growth, and how to destroy them. A few days before this lesson, some hay tea, broth, or cooking gelatine is to be set aside as food ordinarily might be kept. This forms a culture medium for germs. From the sample culture learn to distinguish colonies of bacteria (spots of colored slime), from molds (dry, woolly, or powdery masses). See also page 31.

*Sources, Development, and Destruction of Bacteria.* — Seven slices of potato 1 cm. square by 3 cm. long are placed in separate test tubes, water enough poured over them to cover, and the tubes then plugged loosely with wads of cotton batting that have been baked in an oven.

The water in the test tubes is boiled for a few minutes three days in succession. Only steam should pass through the cotton; if water wets the cotton, a new plug must be introduced and the specimen again boiled. Students may do this in groups according to the number of the class, but each one must inform himself of everything. After the boiling has been completed on the third day, the water is poured off and the tubes are labeled (*a*), (*b*), (*c*), (*d*), (*e*), (*f*), (*g*), and the exercise continued as follows: (*a*) To find whether moisture is necessary for the growth of bacteria, the potato in (*a*) is "inocu-

lated" by transferring some bacteria on a wire from the sample culture to the slice of potato; the latter is then dried slowly, returned to the dried test tube, which is again closed with the cotton; (*b*) to find whether there are germs in the air, the potato in the test tube (*b*) is exposed to the air for about twenty-four hours, and the tube is again stopped with cotton; (*c*) to find if there are any bacteria in tap-water a little drinking water is poured over the slice of potato in (*c*) and poured off again, the cotton plug being returned as soon as possible; (*d*) to learn whether there are any bacteria in dust, some dust is taken from the ledges of the wall or tops of cases and sprinkled on the potato in tube (*d*); this is also to illustrate infection from dirt getting into wounds; (*e*) to learn whether one can destroy bacteria in such cases (wounds, etc.) dust is sprinkled on the potato in (*e*) from the same lot that was used in (*d*) and corrosive sublimate solution, 1–1000 strong, is poured over the dusted slice of the potato and left until the next exercise; the corrosive sublimate is then to be poured off, the cotton plug returned and the tube set aside for results; (*f*) to learn whether "fumigation" of rooms as it is practiced after contagious diseases is effective in killing germs (*f*) is treated with some of the same lot of dust used in (*d*) and the test tube is then set into a chamber (fruit jar) containing half an ounce of formaline and the jar is sealed. Finally, to learn the use of cotton plug and the effect of boiling, (*g*) is set away with nothing but the moist boiled potato in the tube kept carefully plugged with the cotton. In two or three days at room temperature results will begin to show.

The following questions will help the pupil to understand the exercises:

1. How do exercises *b*, *c*, or *d* prove *a*? Show how *g* proves *b*, *c*, and *d*; how *d* proves *e* and *f*; how *c* and *b* prove the two main things shown by *g*.

2. What is a common source of bacteria as shown by *b*, *c*, and *d*? Which exercise illustrates "infected" wounds? Which one "disinfection": (1) by fumigation; (2) by a liquid disinfectant?

3. How may drinking water be freed from the danger of typhoid bacteria?

From home experience the student may be able to tell why things "keep better" on ice and from this he can infer another favorable condition for the growth of bacteria. From the foregoing the stu-

dent may be able to tell one or two of the conditions of the growth of bacteria, how they may be guarded against by knowing their sources, and how they may be destroyed.

NOTE. — Bacteria are microscopic degenerate plants. Some are harmful and others are useful to man, and therefore of economic importance. According to their form they are divided into three groups: (1) Cocci, spherical (like lockjaw germs); (2) Bacilli, rod-shaped (like consumption germs); (3) Spirilla, screw-shaped (like cholera germs).

*Sources of Carbon Dioxide and Ventilation.*[1] — 1. It is assumed that the students have done Ex. E, 3*a*, products in expired air, page 150. If not, then the experiment should now be done to learn also that limewater is a test for carbon dioxide. What do all living things give out to the atmosphere?

2. In a tall glass battery jar are placed a piece of burning candle and a tumbler half full of clear limewater. The jar is covered as nearly air tight as may be, to keep the products of burning in the jar. The candle represents any kind of burning in which organic matter is destroyed. How long does the candle burn in the jar? (The oxygen is not all burned up as is sometimes stated in describing an experiment similar to this one. To get the best result the jar had better be left covered for at least half an hour.) Try to contrive some way of collecting the products of a burning gas jet over limewater.

3. After the battery jar and tumbler used in Ex. 2 have been cleaned, some decaying organic matter, such as wet sweepings that have begun to heat, or rotting vegetables, are placed in the bottom of the jar. The tumbler is again half filled with limewater and set into the jar, and a tight cover put on. This had better be left until the next day. What indication is there of the kind of gas given off by decaying organic matter? Consult the text to learn what kind of organisms cause the decay. Although carbon dioxide is by many not thought to be poisonous, Professor Howell states that 40–50 per cent causes fatal narcosis in animals. What are three chief sources of carbon dioxide in the atmosphere?

4. To learn the weight of carbon dioxide compared with air: A short burning candle is set in the bottom of a jar and some carbon

[1] In order to be on the lookout for carbon dioxide, we must know its common sources.

dioxide[1] is carefully poured into the jar. Watch the candle to see the result. Give reasons for your conclusion as to the relative weight of carbon dioxide and air.

5. To learn the principle of ventilation: (*a*) A lighted candle is lowered into a tall narrow glass jar. How does it behave after some time? Is there any ventilation? (*b*) The candle is again lighted and a tin partition is lowered into the jar so as to make two flues. How does this affect the burning candle compared with (*a*)? A smoking paper or punk-stick held over each flue shows the behavior of air. What is the air doing as shown by the smoke and the flickering flame? What behavior of air underlies all systems of ventilation? What is the principle?

[1] Made same as in Ex. Respiration D 3.

## CHAPTER XVII

### FIRST AID IN EMERGENCIES AND THE SICKROOM

**Unconsciousness.** — If a person is found unconscious, one should, if possible, first determine the cause. In *fainting*, the face is pale and the head cool.

When a person has fainted, lay the body flat on the back. Keep the crowd away, and give plenty of fresh air. Loosen the clothing about the neck and waist. Sprinkle cold water on the face, but do not drench the body with a quantity of water. Apply smelling salts or ammonia to the nostrils; rub the limbs toward the body. If these remedies do not soon restore consciousness, send for a physician. A faint is not usually a serious matter. Bad ventilation, disagreeable odors, or even the over-sweet odors of such flowers as the tuberose, may cause fainting.

When a person is overcome by *heat*, the head is hot. Lay the patient in the shade and pour cold water over the head and chest. If the skin is cold, rub and use restoratives instead of cold water.

When unconsciousness is the result of breathing *gases* or from *electric shock*, use artificial respiration [1] until the physician arrives. If no more than fifteen minutes have elapsed, there is hope of resuscitation.

In case of *alcohol poisoning* (drunken stupor) the breath is the telltale. Give strong coffee and arouse, if possible, by cold water on the face; then put to bed or keep the unfortunate quiet.

[1] See page 344.

**Bleeding from Wounds.** — By pressing gently either side of the wound, one can tell where best to apply stronger pressure until clotting stops the flow of blood. In case of severe wounds, pressure should be applied immediately to the wound. Sometimes it is well to make a plug of cloth and press upon the cut.

*In case of bleeding from an artery,* the blood comes in jets. Pressure should be applied between the cut and the heart. To know where to apply the pressure, a study of the course of the main arteries should be made. By studying Fig. 28 it will be seen that the arteries to the arms pass down the inside of the upper arm. Here they come near the surface. At the elbow the artery is near the skin in the angle of the elbow. The artery which makes the pulse at the wrist is well known. By putting a baseball under the armpit and pressing the arm down firmly, the artery may be compressed.

**Wounds in the Thigh.** — The femoral artery comes near the surface in the groin. Pressure may be applied here in the same way to stop bleeding from a cut farther down the thigh. In the angle back of the knee, pressure may compress the artery supplying the leg.

**Bleeding from Veins.** — In case of bleeding from veins, holding the part up may check the flow. If necessary to apply pressure, it should be beyond the cut, instead of between it and the heart, as in the case of the artery.

**Hemorrhage from the Lungs or Stomach.** — Blood from the lungs is bright, frothy, and salty; that from the stomach is dark and sour. In case of bleeding from the lungs or stomach, let the person rest quietly on a lounge or easy-chair. Give him some bits of ice to swallow.

**Bleeding from the Nose.** — Nosebleed may sometimes be

stopped by pressing firmly at the base of the nose. Do not lean forward, as this position aids the flow. Sit up, holding up the head, and hold a cloth under the nose. Apply cold water or ice to the nose and to the back of the neck. If this does not stop it, inject cold water, with a little alum in it, into the nose. Do not use warm water. If these attempts fail, a long strip of cloth may be used to plug the nostril, pushing the cloth in a little at a time, and leaving the ends so it can be pulled out. This should not be removed until a long time after the flow is checked, as it may start the bleeding afresh. After an attack of this kind avoid blowing the nose, as this often starts bleeding again.

**Broken Bones.** — Keep the patient as quiet as possible till the physician arrives. There need be no anxiety if the physician is delayed, as ordinarily no harm comes from waiting. If there is inflammation, cold water may be applied. Cooling applications are desirable in case of severe bruises. If it is necessary to carry the patient, lay him on a board, or at least keep the injured part as quiet as possible; a cane or umbrella may be tied alongside a leg, and supported by a pillow or a coat. Sometimes the sharp ends of the bones may cut the flesh or even the blood tubes.

**General Cautions Concerning Wounds.** — Wounds that do not bleed freely should be squeezed and sucked — whoever does this, spitting out what is extracted — so as to remove germs. Then the wound should be treated with a disinfectant.[1] A 10 per cent solution of permanganate of potash (or 5 per cent solution of carbolic acid) makes a good disinfectant. Small and deep wounds should be squeezed until the disinfectant has penetrated to every part.

[1] See Appendix, page 361.

Pin pricks and other small wounds that do not bleed freely are more dangerous than larger ones where the profuse bleeding washes out germs.

In later treatment, deep wounds must be kept open at the surface until they heal from the bottom upward. Wounds properly treated once with a disinfectant, if kept clean, should heal without the formation of "matter" or pus. In case of discoloration, swelling, and pain, a physician must be consulted.

**Bites of Animals.** — The bites of ordinary animals should be treated the same as wounds — with some disinfectant. The more dangerous kinds are those of rabid animals and snakes that have poison fangs — the rattlesnake, the copperhead, and the water moccasin. As their poisons are not stomach poisons there is no harm in sucking the wound if there are no breaks in the skin about the mouth and if the poison is spit out promptly.

If the animal is known to be rabid (a cat, dog, or other animal may have hydrophobia), or the snake is a poisonous one, the first treatment is essentially the same. The object is to prevent as much as possible of the poison from getting into the blood circulation, and for this purpose a strong twisted cloth or cord is to be tied around the limb above the bite and twisted tightly with a stick (*tourniquet*). This will also benumb the limb somewhat so that the cutting of the wound is not as painful. The cutting of the wound lengthwise through each "tooth mark" is to induce bleeding to wash out the poison. In each case a physician should be called promptly. In both cases the wound may also be cauterized, *i.e.*, burned out with white hot iron or lunar caustic — strong nitric acid; or by the injection of a strong solution of permanganate of potash with a hypo-

dermic syringe the surrounding tissues may be killed and the poison destroyed.

A person bitten by a *mad* dog must be treated in a Pasteur Institute. If there is any doubt about a dog having rabies he should be shut up until this is determined.

If the heart action becomes weak from snake poison, a heart stimulant — a few drops of aromatic ammonia in a teaspoonful of water — may be given every 10 minutes. Alcoholic liquor increases the danger when taken in quantity.

**Treatment of Burns.** — Plunge the burned part into cold water. The main thing to be done is to cool the burned surface and shut out the air. The oxygen of the air gives pain to the raw surface, and germs in the air will aggravate the wound and retard healing. As soon as possible apply a solution of cooking soda (a tablespoonful of bicarbonate of soda to a teacup of water); or lay a wet cloth on the burned part and put the soda on the cloth. Afterwards apply vaseline, and renew the vaseline till the wound is healed.

A mixture of equal parts of sweet oil and limewater makes a good liniment for dressing burns. Flour should not be used because it is hard to remove without taking the skin off with it. A mixture of cooking soda and vaseline makes a good ointment for burns.

After exposure to "poison ivy," bathe the part in a mixture of two teaspoons of carbolic acid (pure), two tablespoons of glycerin, and one half pint of water.

**Danger from Burning Clothing.** — If the clothing takes fire, there is added to the danger of burning the body, the further risk of inhaling the flame and heated air. It is best to lie down and roll or wrap the body in any clothes at hand — rugs, shawls, etc. Running serves to fan the

flames. Hence, if a person whose clothing is on fire is seen to be thoroughly frightened, and has lost presence of mind and is running, the best thing to do usually is to grasp and get him to lie on the ground, putting a wrap of some kind around the body at the same time if possible. Rolling on the ground or floor in itself would very likely put out small flames.

**Burning Buildings.** — If easy escape is cut off, it is best to find any kind of cloth — towel, handkerchief, or even a rag — and wet it, if possible. When this is held over mouth, nose, and eyes, one can pass through dense smoke without danger of inhaling smoke or flame. Near the floor there is less heat and smoke, so that one can often creep where he could not walk. If one must pass through a door beyond which there is fire, the door should be opened cautiously, as the gases in the burning room, mixing with fresh air, may explode and overcome a person entering hastily.

Coolness is a most important factor in escaping from such dangers. It is the history of burning buildings that more people are killed by frantic efforts to escape, especially where panic follows false alarm, than by being burned to death. A person with sufficient presence of mind to sing, or play on an instrument, has many times saved people from panic.

**Suffocation.** — When this takes place as the result of breathing illuminating gas or coal gas, it is practically a case of poisoning. The carbon monoxide of these gases has united with the red corpuscles of the blood so that they cannot easily take oxygen.

When suffocation is caused by carbon dioxide, as it sometimes is from going down into deep cisterns, wells, or silos, it is less dangerous, for there is no poisoning. The carbon

dioxide has merely shut out the air.[1] In either case, the main chance is in carrying on artificial respiration (page 344) until the physician arrives. If the sufferer is treated soon after the accident occurs — within fifteen minutes — there is good hope of restoration. Even if a half hour has elapsed resuscitation should be attempted.

**Precautionary Measures.** — Any one about to go down into places that may contain carbon dioxide should know that this gas produces a prickling sensation in the nose, the same as is experienced in drinking soda water. Such a warning should be promptly heeded. The workman should ascend and the place should be tested by lowering a lighted lantern tied to a cord. If the flame of the lantern is put out, it is not safe for a man to descend into the well or cistern. If work attempted must be carried on, the carbon dioxide may be removed by throwing a thin paste of lime and water into the bottom of the well, or by lowering a bunch of burning straw or paper on one side, thereby causing an upward current.

## Drowning

**Drowning and Artificial Respiration.** — In suffocation from drowning, the lungs are full of water. If the body does not quickly come to the surface, several fish-hooks on lines with sinkers, dragged over the bottom may help to bring it up. If the body is not recovered in from 15 to 30 minutes after the accident, there is no hope of resuscitation; within 10 minutes there is every hope of recovery.

**Avoid Delay.** — A moment may turn the scale for life or death. Dry ground, warmth, hot drinks, at this mo-

[1] The above is the statement in many elementary books. In Howell's *Text-Book of Physiology* it is stated that 40–50% carbon dioxide in the air causes fatal narcosis in animals.

ment are nothing — artificial breathing is everything — is the one remedy — all others are secondary.

Do not stop to remove wet clothing. Precious time is wasted.

**First restore Breathing.** — Give all your attention and effort to restore breathing by forcing air into and out of the lungs. If the breathing has just ceased, a smart slap

Fig. 111. — Resuscitation from drowning (Lincoln)
Position 1 — Emptying the lungs of water

on the face or a vigorous twist of the hair will sometimes start it again, and may be tried incidentally.

Before natural breathing is fully restored, do not let the patient lie on his back unless some person holds his tongue forward. The tongue by falling backward may close the windpipe and cause fatal choking.

*Prevent friends from crowding around the patient and excluding the fresh air;* also from trying to give drinks before the patient can swallow. The first causes suffoca-

tion; the second, fatal choking. Quickly carry or roll the body to the nearest clear spot, but do not waste time in looking for a shelter.

1st. Tear or cut away any tight clothing around the neck or the waist, and lay the body *face down*.

2d. Clasp your hands under the stomach and suddenly lift the body until the mouth — but not the forehead — is free from the ground, and the water runs out of the mouth, as shown in Fig. 111. If the body is too heavy to lift, pro-

Fig. 112.—First breathing movement. Notice pressure on the lower ribs, weight of the rescuer aiding. Air is forced out of lungs.

ceed as in Nos. 3 and 4. Repeat once, then turn the body over and wipe out the mouth with a cloth over your finger.

3d. (*a*) Again turn the body down, with the face turned sidewise, laying a rolled coat or something of equal size under the stomach. (*b*) Now, kneeling beside the body, slowly push downward and forward with both hands directly over the lower ribs, while *saying* "one thousand, three hundred, and fifty-four." [1] (Fig. 112.) This movement (*b*) forces stale air out of the lungs.

[1] Of course, saying any similar number will do, as this is to make as sure as possible of pushing down for about two or three seconds. As soon as the rescuer has sufficiently recovered from his excitement to take normal breath,

4th. Sit back on your legs so as to raise your weight and pressure from the body — as shown in Fig. 113[1] — while again saying "one thousand, three hundred, and fifty-four." Keep the hands on the body. This movement of the body releases the compressed chest, and its expansion draws air into the lungs.

Fig. 113.—Settling on his hips the rescuer lets the back and chest expand. Air is drawn into the lungs

Nos. 3 and 4 constitute artificial respiration and should be continued until natural breathing takes place.[2] It may require one or two hours. *Do not give up too soon;* you are working for life. Any time within two hours you may be on the very threshold of success without there being any sign of it. If there is help at hand, others should rub the limbs toward the body and help restore circulation.

**Restoring Heat.** — After breathing has commenced, restore heat to the body. Wrap the patient in warm blankets, apply bottles of hot water, or stones warmed in a fire, being careful not to burn the skin. This may be avoided by wrapping the stones in cloth. Rubbing the

he can follow his own movements, pushing down when he breathes out and rising when he inhales.

[1] Figs. 112 and 113 after *Michigan State Board of Health Bulletin.*

[2] This is essentially the Schäfer method.

limbs and body also helps to restore heat. *Warm the head nearly as fast as the body, lest convulsions come on.* Rubbing the body with warm cloths or the hand, and slapping the fleshy parts, may assist to restore warmth, and also the breathing. If the patient can *surely* swallow, give hot coffee, tea, milk, or five grains of carbonate of ammonia in a quarter of a tumbler of hot water. Place the patient in a warm bed, and give him plenty of fresh air; keep him quiet.

**Prevention.** — Those who cannot swim should not go out in any boat unless accompanied by a good swimmer, and not then, except in shallow water — not deeper than to their shoulders. Those who wish to enjoy the water should learn to float and swim, and while bathing should practice so as to fall into water safely. Floating may be done by taking a deep breath and holding mouth and nose, while settling backward in water that is not too deep. When the head is thrown far backward and the chest up one floats easily, with only the face above the surface. In this position, keeping the lungs well filled, one can breathe lightly for a long time.

**When a Boat Upsets.** — In case an ordinary rowboat is overturned, one should not attempt to climb into it or upon it. It takes very little to float a person in water, as the body is only a little heavier than water. Those who can swim should help those who cannot to get hold of the edge of the boat, but not permit them to climb upon it. A small plank will float a person if he will not try to lift much of his body out of the water.

## Poisons and their Antidotes

Several of the common drugs and remedies kept about the house are more or less poisonous. The proper antidote

for each should be known and kept at hand. In the first place, all such materials should be kept locked up so that they will not be taken by mistake, as in the haste of getting medicine in the night. Again, all grown persons in the family should be instructed as to the effects of each poison, and taught its antidote. Whenever any new poisonous drug is bought, pains should be taken to learn about it, and to procure an antidote. Every one ought to know that strychnin and opium should not be kept in the house.

**Objects of Treatment.** — Treatment aims at three things: (1) to get rid of the poison, (2) to neutralize what remains and prevent further action, (3) to remedy the effects already produced.

1. **Mustard a Common Emetic.** — The most common emetic is mustard — a tablespoonful in a cup of warm water; give half of it, following with free drinking of warm water, then give the rest of the mustard. Do not wait for it to dissolve, but stir quickly and give at once. Provoke vomiting by tickling the throat with a feather or with the finger. If the mouth of the patient cannot readily be opened, insert the thumbs inside the cheeks and back of the teeth. If mustard is not at hand, a strong solution of table salt will serve. In a few cases, such as poisoning by ammonia, lye, etc., it is considered best not to administer an emetic, but to try to neutralize the effect with vinegar.

2. **Neutralize the Poison.** — To neutralize a poison this general rule should be known: an alkali may be neutralized by an acid, and *vice versa*. For example, lye with vinegar, carbolic acid with whiting or magnesia, etc. Some acids and alkalies are always about a house. (See Appendix.)

3. **Give Something Soothing.** — After any irritant poison, some mild and soothing substance should be given —

white of egg, milk, mucilage and water, flour and water, gruel, olive, or castor oil. These materials are partly for neutralizing the poison, and are also soothing in their effect. If a patient is drowsy, some stimulant may be given, as strong coffee (after opium). Of course a physician should be sent for immediately, as the after treatment is of great importance.

The tables of "Poisons, their Symptoms, Antidotes, and Treatment," in the Appendix, are taken from the excellent *Text-Book of Nursing* by Clara Weeks-Shaw.

## General Care of the Sick

**Qualities of a Nurse.** — Every boy and girl ought to learn something about the care of the sick, as any one is likely to be called on to do this kind of work. Good nursing is often "half the battle." In the first place, the nurse should faithfully follow the directions of the physician. This obedience should be complete as to admission of visitors, as well as in administering medicine. The nurse often yields to the persuasion of some unwise friend, "It won't do any harm for him to see me." Have the physician's directions written out plainly, so that they may not be forgotten.

The nurse should have a quick sympathy, and make the patient feel that all that can be done for his comfort will be done; yet this sympathy must not lead the nurse to do anything for, or give anything to, the patient contrary to the orders of the physician. The nurse should always be cheerful, even when the patient is annoying in his demands. The patient is not "himself," and no attention should be paid to his unnatural irritability.

Never let yourself get drowsy when acting as nurse.

Get up and walk about, get a breath of fresh air, and if inclined to be drowsy do not allow yourself to settle back in an easy-chair. If watching all night, take a good lunch in the middle of the night; coffee may help to keep you awake. It is not to be expected that one who has worked hard all day outdoors will be likely to keep awake all night.

**Sympathy with the Patient.** — One of the necessary characteristics of a good nurse is the power of imagination. "How would I feel, and what would I like to have done for me, if I were in his place?" This feeling will lead the nurse frequently to raise the patient's head and turn the pillow — the coolness of the other side of the pillow is refreshing; to give sips of cool water; to see that the patient does not suffer for want of a bath; in giving a bath to do the work thoroughly.

**Hope.** — While it is not best to deceive the patient as to his condition, there should at all times be kept up an air of cheerfulness and hope. If the physician can inspire with confidence, and the nurse give unflagging good cheer, the chances of recovery are vastly improved. Nothing sustains like hope.

**Bathing the Sick.** — In bathing a weak person only a part of the body should be moistened at a time; after this is thoroughly dried, another part may be washed; it is often necessary to do all this work under the bed clothing.

**Changing the Bedding.** — In changing the bed clothing move the patient to one side of the bed, push the clothing along close to his body, and place the clean bedding on the other side; then move the patient back, remove the soiled linen, and smooth out the clean. It is often necessary to warm the sheets first; they should be thoroughly dry.

**Bandaging, Preparing Food, etc.** — It is well for every one to know something about bandaging, the preparation of food for the sick, etc. Space here will not allow further treatment of these subjects, and the student is referred to treatises on the care of the sick.

Raise the head with the hand, or bolster the patient up, when giving drink; or if the patient is very weak, use a bent tube, so that he will not have to lift his head. The nurse should know how to prepare any food that may be needed during the night. An oil stove or gas stove is very desirable for cooking, or heating poultices, as an ordinary wood or coal fire is likely to die down, making it impossible for the nurse to do this work quickly. It is often necessary to take advantage of a favorable time, as when the patient wakens.

**The Sickroom.** — The patient should have a cheerful room, but the bed should be so placed that the light will not come too strongly into his face. Evidence of illness, such as medicine bottles, should be kept out of sight so far as possible. Keep the air of the room pure. Remove excreta and everything offensive just as soon as possible. Do not rely on *feeling* as to temperature, but keep a thermometer in the room.

**Sweeping the Sickroom.** — Do not allow the room to be swept with the ordinary broom. The room should have rugs that can be removed and shaken, and the floor wiped with a moist cloth. If the room is carpeted it may be swept with moist tea grounds or newspaper torn in shreds. Any dusting should be avoided; furniture may be wiped with a damp cloth. A vacuum cleaner is best of all.

Most lamps, when turned low, give off a disagreeable odor. It is better to have a very small lamp burning at

full height than a large one turned low; sperm candles are recommended.

**Avoidable Noises.** — In walking on tiptoe, often floors and stairs are made to creak, when they would not in ordinary circumstances. It takes little reflection to see that in walking thus one brings more weight than usual on a smaller part of the floor, and is therefore more likely to spring a board in the floor; it is better to walk flat-footed. Wear an easy pair of shoes; an old pair is likely to be quiet. In the effort to be quiet many make a mistake; do not whisper, as it disturbs more than talking, and also has an air of secrecy that rouses suspicion in the patient.

It is well known that a sneeze may be prevented by firmly pressing on the upper lip, or holding the breath for a moment. This may enable a nurse to keep from waking a very sick patient when, at a critical point, sleep is almost a question of life or death. To prevent coughing take cough drops; or a swallow of water will relieve the tickling in the throat.

## QUESTIONS FOR REVIEW

1. In case of unconsciousness, why is it important first to determine the cause?

2. What is the difference between the treatment for fainting and heat prostration (sunstroke)?

3. How is unconsciousness that is caused by electric shock or gases to be treated?

4. What is the general method of stopping the flow of blood from wounds?

5. How is the method for stopping the flow from arteries different from that used when bleeding from veins? Why?

6. What is the best thing to do until the surgeon comes to set broken bones?

7. How should slight wounds be treated? Why are they more dangerous?

8. What precaution is to be taken in the healing of deeper wounds? Why?

9. What two things are to be done in the treatment of mad-dog bite?

10. Why should the patient have Pasteur treatment? When should the dog be watched?

11. Why is it necessary to be quick about the treatment for snake bite?

12. What are the remedies for burns? What is their use?

13. In what way is burning clothing to be extinguished? Why not run?

14. What precautions are to be observed in a burning building? Why?

15. In case of suffocation what treatment is given?

16. What are the successive steps in the resuscitation of the drowned? Reasons.

17. How may drowning accidents be prevented? How may one keep afloat when a boat is upset?

18. What are three steps in the treatment for stomach poisons? Give illustrations.

19. What are the better preventive measures that every one should exercise?

20. Why should boys and girls learn home nursing?

21. What are the desirable qualities in a nurse (*a*) from the standpoint of the patient? (*b*) from the standpoint of the doctor?

22. How may the bedding be changed without lifting the patient?

23. What are desirable features in a sickroom?

24. How may dust be avoided in a sickroom while cleaning it?

25. What objectionable noises in the sickroom may be avoided? How?

# APPENDIX

**On Experimental Exercises.** — *Using the Exercises:* Pupils may either participate in the exercises accompanying the chapters, or do them individually and write out results and conclusions, if there is time for such work. While a laboratory is desirable, yet all the exercises can be done at a table, by sections, if the class is large. On a subsequent page desirable apparatus is listed.

The teacher may go through the exercises before the class, using them to increase interest. Where there is a laboratory with apparatus, each pupil may take part, the teacher illustrating how to do some of the earlier exercises. If pupils are required to observe their own results and to tell what is learned from them, the exercises will have the value of problem solving, besides practice in manipulation.

There should always be a "control," or "proof result"; *e.g.*, (*a*) In learning acid and alkali tests, litmus paper should also be tried in water. (*b*) The caustic soda and copper sulphate solution (test for glucose) should be boiled to see that the test color is not obtained *until* glucose is added. (*c*) In learning the limewater test for carbon dioxide, a tube of pure water should be treated the same as the limewater.

**Writing out the Exercises.** — If the exercises are to be written out, it is suggested that this be done under the following captions: (1) *Purpose* of exercise, telling what is to be learned; (2) *Operations,* telling briefly what is done; (3) *Results* observed. It should be borne in mind that a conclusion cannot be drawn from the statement of one result. Before telling what is learned there must be comparison of the result with the "control," previously mentioned, or with some known fact. This step may be called (4) *Discussion,* — to be followed by (5) the *Conclusion,* which must answer or conform to the purpose. If the students are required to copy the *purpose* and *operations* as given in the exercises, much time will be saved in reading, as the teacher will need to read all the results and conclusions most carefully.

The descriptions of operations are purposely cast in the third person to avoid the wearisome way pupils have of using the *imperative*, directing themselves what to do, and also to encourage conscientious students who do not like to say " we did so and so," when the teacher sets up the experiment.

**Specimens and Animals.** — Live animals should not be used in experiments that will cause them to suffer. Those teachers who have no models and those who prefer specimens may secure heads, legs, blood, heart, lungs, stomach, and intestines from a meat market. Those who can demonstrate organs of an animal just killed by chloroform will know how to open the body cavities and show the lungs, the beating heart — in case of the frog — the abdominal viscera, coagulating blood, etc. Pupils should not be compelled to handle or dissect specimens, though all can be expected to look on, or to make drawings and write notes, if this is a requirement.

On the other hand, pupils can gradually overcome their repugnance, and they should do all they can to carry out the class program. It is frequently an advantage to have a demonstration session out of class time, attended by all students who are not over-sensitive, or not likely to be made ill by dissections.

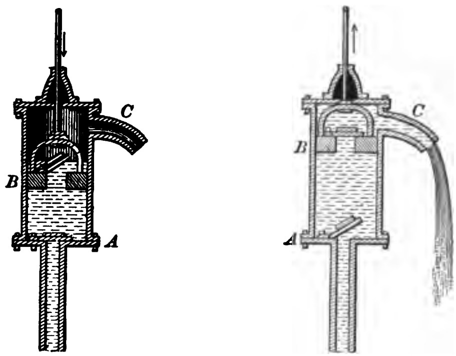
**Home Work.** — It is suggested that there should be home exercises, for practice in copying useful diagrams, such as that of circulation (page 107), or of the whole body showing the organs in position (page 37), and other illustrations that cannot be made from specimens. The student should be able to produce these as a test in class without the aid of the book. Illustrations in books are not studied enough. This should be made a regular part of exercises. However, no illustrations, except those drawn from specimens, should be copied in the notebooks.

Many practical exercises may also be performed at home: on the work of organs and muscles; on amount of water in foods; on the pulse and heartbeat; many exercises with organs of special sense and the voice; yeast fermentation, and decay; the heating and ventilation of a living room; practice in preparing and using bandages; practice in artificial respiration exercises.

Much good may be done by asking students to bring lists of " home remedies," discussing these in class so as to point out those that are harmful or even dangerous, as well as those that are useless.

**A Paper Drinking Cup.** — Fold in the middle, a clean piece of paper about 10 by 10 inches square; again fold this double sheet across the middle. Turn and press one of the four corners out and down to the opposite corner. Then press the other three corners out and down in the opposite direction and open the pocket or cup thus formed for use.

**A Pump.** — Study the figure of the pump to see (1) how raising the handle will open the valve (*B*) in the plunger, letting water pass above




the plunger; (2) how pushing the handle down lifts the water that is above the plunger, closing this valve and opening the valve (*A*) in the suction pipe; water rises. What makes the water follow the rising plunger? How does the rising plunger affect the air pressure inside and outside of the suction pipe (pump)?

## A LIST OF USEFUL BOOKS[1]

*Bacteria — Yeast and Molds in the Home.* Conn. Ginn & Company. General reading; experiments in Appendix.

*Biology, Introduction to.* Bigelow. Macmillan Company. Useful for "human biology."

[1] Teachers are no doubt familiar with the current textbooks in Physiology, so that no particular mention of them need be made. A monthly list of the bulletins of the Department of Agriculture at Washington is to be had for the asking. Circular No. 19 is a special list of books, classified by subjects. State Boards of Health also issue bulletins which teachers may receive as they are issued, if application is made for them.

*Biology and Its Makers*. Locy. Henry Holt & Co. Useful for biographies.

*Bodies — Sound Bodies for Our Boys and Girls*. Blaikie. Harper & Brothers. Though old, this is still valuable.

*Children's Diet in Home and School*. Hogan.

*Dietary Studies*. Irving Fisher. *Journal of the American Medical Association*, Vol. xlviii, No. 16.

*Health Studies*. Hoag. D. C. Heath & Co. Elementary; has many good illustrations; gives full and valuable list of literature.

*Human Body, The*. Advanced Course, Revised. Martin. Henry Holt & Co. A good reference book for teachers.

*Human Mechanism*. Hough and Sedgwick. Ginn & Company. An advanced book; largely hygiene; no practical exercises.

*Hygiene for Girls*. Richards. D. C. Heath & Co. Just as suitable for boys; gives Snellen's eye-test letters and figures.

*Hygiene, Lessons in Practical*. Ravenhill, Alice.

*Insects and Disease*. Doane. Henry Holt & Co. For general reading.

*Life, The Efficient*. Gulick. Doubleday, Page & Co. General reading.

*Life of Laura Bridgman*. Howe and Hall. Little, Brown & Co. The story of a girl with but "one sense."

*Nutrition and Diet*. Conley. American Book Co. Gives illustrations of Atwater's respiration calorimeter, ménus, etc.

*Pathfinders of Physiology*. Dempster. Detroit Medical Journal Co. As its title implies, it gives historical development of some phases of physiology; gives also account of the case of Alexis St. Martin.

*Physiology and Hygiene*. Walters. D. C. Heath & Co. A course for upper classes in high school.

*Physiology, Practical and Descriptive*, Part II. Colton. D. C. Heath & Co. A laboratory guide; giving a good list of literature and apparatus.

*Physiology, A Text-Book of*. Howell. W. B. Saunders Co. Comprehensive and authoritative; for teachers or medical students.

*Sanitary Science and Public Hygiene, Principles of*. Sedgwick. Macmillan Company. An extensive work for reference.

*School Sanitation and Decoration*. Burrage and Bailey. D. C. Heath & Co. A manual.

## LIST OF DESIRABLE APPARATUS AND CHEMICALS

The quantities are enough for a class of 15.

Test tubes $\frac{3}{4}$ in. by 5 or 6 inches long; twice as many as there are students in the class. Holders are convenient but not necessary.

Test tube racks (3). Could be made by students.

Test tube brushes (6).

Alcohol lamps or Bunsen burners (if there is gas) — one for every two students.

Sauce dishes (porcelain, 2 dozen).

One oven for drying and sterilizing.

Dentist's sheet rubber — one square foot.

1 microscope. A physician may lend one.

1 pair bone forceps, 7 inch; stout shears will do.

1 mitre saw; will do for bone and wood.

1 lactometer.

1 retort stand, 20 in. standard; 3 rings and 2 clamps.

Assorted corks, 2 dozen, from $\frac{1}{2}$ to $1\frac{1}{2}$ in. diameter.

Perforated rubber stoppers; 1, $\frac{3}{4}$ inch. 2, one inch.

Glass tubing, $\frac{1}{4}$ in. internal diam., 5 ft.; $\frac{1}{8}$ in. internal diam., 5 ft.

Rubber tubing, $\frac{1}{4}$ in. internal diameter, 5 ft.

2 Florence flasks, 250 c.c. capacity.

Medicine droppers, 1 or 2 dozen.

Graduates, a one-ounce and an 8-oz. One side graduated in c.c.

Chemical thermometers — 3 to 6.

Magnifiers (tripod), 15.

Bottles, 6 oz. liquid, wide mouth, 12.

Cork borers, one set, 1–3.

Foot rules, both English and metric scales.

Battery jars, 3, tall; one gallon capacity.

Tumblers, 15.

Models of eye, ear, heart, and larynx are very desirable. These three would cost about $20.

A stereopticon and a manikin are desirable if there is money available for such purposes.

Models and specimens may be had from the Ward Natural Science Establishment, Rochester, N.Y., and the Kny-Scheerer Co., New York City.

Microscope, glassware, etc., may be had from the Spencer Lens Co., Buffalo, N.Y., and the Bausch and Lomb Optical Co., Rochester, N.Y.

*Chemicals*

Hydrocholoric acid, 3 lb.
Nitric acid, 2 lb.
Ammonia, 5 lb.
Copper sulphate, ½ lb.
Chloroform, ½ lb.

The commercial reagents will do for the above.

Iodine, re-sublimed, 1 oz., or 1 qt. *brown* solution in KI.

Quicklime, 2 lb.

Alcohol, denatured, 2 gal. if alcohol lamps are used, otherwise one-half gallon.

Formaline, 1 pint.

Olive oil, 1 pint.

Granulated grape sugar, 1 pound.

Pancreatin, one-half ounce to one ounce.

Pepsin, one-half ounce to one ounce.

Rennin, one-half ounce to one ounce.

Litmus paper; it is best to order this in the small books, ½ doz. pink, and ½ doz. blue.

## CONTAGIOUS AND INFECTIOUS DISEASES[1]

| Disease | Days of Incubation | Period of Isolation |
|---|---|---|
| Whooping Cough | 2 to 11 | Until cough is cured |
| Typhoid Fever | 12 to 21 | 3–8 weeks |
| Smallpox | 8 to 15 | Until healed and free from scales |
| Mumps | 8 to 30 | Two weeks from taking disease |
| Scarlet Fever | ½ to 49 | Until discharge from head and the fever are cured |
| Measles | 5 to 15 | Until scales are gone and throat trouble cured |
| Hydrophobia | 12 to 2 years | Not contagious. Preventive treatment absolutely necessary |
| Diphtheria | 1½ to 15 | Two weeks after membrane disappears. |

[1] Modified from Fitz.

## ANTISEPTICS AND DISINFECTANTS

The following is chiefly from Sternberg's *Manual of Bacteriology*, and embodies part of the "Report of the Committee on Disinfectants" of the American Public Health Association.

**Antiseptic Defined.** — An antiseptic is a substance having the power to prevent or destroy putrefaction, or, what is the same thing, the bacteria upon which putrefaction depends.

**Disinfectant Defined.** — A disinfectant is a substance that can destroy disease germs.

**Disinfection Defined.** — Disinfection is the destroying of disease germs by means of heat, chemical substances, fumigation, or by fresh air.

"The injurious consequences which are likely to result from such misapprehension and misuse of the word 'disinfectant' will be appreciated when it is known that recent researches have demonstrated that many of the agents which have been found useful as deodorizers or as antiseptics are entirely without value for the destruction of disease germs."

**An Antiseptic, but not a Disinfectant.** — "This is true, for example, as regards the sulphate of iron, or copperas, a salt which has been extensively used with the idea that it is a valuable disinfectant. As a matter of fact, sulphate of iron in saturated solution does not destroy the vitality of disease germs, or the infecting power of material containing them. This salt is, nevertheless, a very valuable antiseptic, and its low price makes it one of the most valuable agents for the arrest of putrefactive decomposition."

**Methods of Disinfecting.**[1] — The committee would make the following recommendations with reference to the practical application of these agents for disinfecting purposes: —

**For Excreta.** — (*a*) In the sickroom: —

1. Chloride of lime, four per cent.

In the absence of spores: —

2. Carbolic acid in solution, five per cent.
3. Sulphate of copper in solution, five per cent.

[1] From the "Report of the Committee on Disinfectants" of the American Public Health Association.

(*b*) In privy vaults: —

1. Mercuric chloride in solution, 1 : 500.
2. Carbolic acid in solution, five per cent.

**For Clothing, Bedding, etc.** — (*a*) Soiled underclothing, bed linen, etc.

1. Destruction by fire, if of little value.
2. Boiling at least half an hour.
3. Immersion in a solution of mercuric chloride of the strength of 1 : 2000 for four hours.
4. Immersion in a two per cent solution of carbolic acid for four hours.

(*b*) Outer garments of wool or silk, and similar articles, which would be injured by immersion in boiling water or in a disinfecting solution: —

1. Exposure in a suitable apparatus to a current of steam for ten minutes.
2. Exposure to dry heat at a temperature of 110 degrees C. (230 degrees F.) for two hours.

(*c*) Mattresses and blankets soiled by the discharge of the sick: —

1. Destruction by fire.
2. Exposure to superheated steam, 105 degrees C. (221 degrees F.) for ten minutes. (Mattresses to have the cover removed or freely exposed.)
3. Immersion in boiling water for half an hour.

**Furniture and Articles of Wood, Leather, and Porcelain.** — Washing several times repeated, with: —

1. Solution of carbolic acid, 2 per cent.

**For the Person.** — The hands and general surface of the body of attendants of the sick, and of convalescents, should be washed with: —

1. Solution of chlorinated soda diluted with nine parts of water, 1 : 10.
2. Carbolic acid; 2 per cent solution.
3. Mercuric chlorid, 1 : 1000.

**For the Sickroom.** — (*a*) While occupied, wash all surfaces with: —

1. Mercuric chlorid in solution, 1 : 1000.
2. Carbolic acid in solution, 2 per cent.

(*b*) When vacated, fumigate[1] with sulphur dioxide for twelve hours, burning at least three pounds of sulphur for every thousand cubic feet of air space in the room; then wash all surfaces with one of the above-mentioned solutions, and afterward with soap and hot water; finally throw open doors and windows, and ventilate freely.

## VITAL STATISTICS OF INTEREST

**Number of Sweat Glands.** — The number of sweat glands may be as high as 3500 in a square inch, and the average is estimated at 2800 per square inch; as there are about 2500 square inches of body surface, it is readily computed that there are several millions of sweat glands. If placed end to end, the sweat glands of the body would be eight miles long.

**Circulation.** — Rate of blood flow: in the large arteries, from 12 to 16 inches a second; in the caval veins, about 4 inches a second; in the capillaries, from 1 inch to 1.5 inches a minute. A portion of the blood makes the complete circulation (in a horse) in less than half a minute. This is found by putting some readily detected chemical into one jugular vein, and noting how soon it appears in the other jugular vein. The time necessary for all the blood to pass through the heart is estimated as follows: Each ventricle pumps about six ounces of blood at each stroke. At this rate thirty strokes, 25 to 50 seconds (or less), would have pumped all the blood in the body. Still, some of the blood (from the shorter circuits) may have been pumped twice, and some (from the longer routes) may not yet have been around once. And since the total amount of blood has been only approximately determined, these figures are not very accurate.

Number of blood corpuscles to the cubic inch, about 83,000,000.

**Dr. Tanner's Forty Days' Fast.** — (Newspaper Account). No Food but Water Taken. When Dr. Tanner came to New York from Minnesota he weighed 184 pounds. He was six weeks making arrangements for his fast; and when he began his experiment his weight was 157½ pounds. He weighed 121½ pounds on the day his

[1] Formaldehyde, or formalin, is now more commonly used. For every 1000 cu. feet of room space 1 pint is thrown on a sheet, loosely hung up, to facilitate quick evaporation: or ½ pint is put in a large earthenware or porcelain dish with one ounce of permanganate of potash. The room must be immediately left and tightly closed.

fast ended. He had therefore lost 62½ pounds since he came to the city, and 36 pounds since he began his fast. Dr. Hammond, the well-known New York physician whose assertion that a forty days fast was a physical impossibility led Dr. Tanner to make the attempt, came out in a card in the New York papers declaring that he believed the fast had been fairly conducted.

On each day of his fast Dr. Tanner weighed as follows: —

| Day | Pounds | Day | Pounds |
|---|---|---|---|
| 1st | 157½ | 25th | 131½ |
| 3d | 153 | 26th | 131½ |
| 5th | 147½ | 27th | 130½ |
| 7th | 143½ | 28th | 129¾ |
| 11th | 139¾ | 29th | |
| 13th | 136¼ | 30th | 130 |
| 14th | 133 | 31st | 128 |
| 16th | 132 | 32d | 127½ |
| 17th (8.30 P.M.) | 133½ | 33d | 126½ |
| 17th (11 A.M.) | 135½ | 34th | 126½ |
| 18th | 136½ | 35th | |
| 19th | 136 | 36th | |
| 20th (4 P.M.) | 135½ | 37th | 125½ |
| 20th (5 A.M.) | 135 | 38th | |
| 21st | 135 | 39th | 122½ |
| 22d | 133½ | 40th | 121½ |
| 24th | 132½ | | |

**Cavities of the Body.** — 1. Mucous cavities (open to the external air). Digestive tube, respiratory passages, genito-urinary passages, external and middle ear, etc.

2. Serous cavities (closed). They may all be said to be lymph cavities. They are the lymph spaces throughout the body, and the large spaces, called the pleural cavity around the lungs, the pericardial cavity around the heart, the peritoneal cavity in the abdomen, the arachnoid cavity around the brain, and a similar one along the spinal cord.

3. Synovial cavities in the joints.

4. Blood cavities, — the inside of the heart and blood tubes.

5. Secretion cavities, — the cavities and tubes from the glands; for example, the bile sac and its duct.

6. Bone cavities.

## COMPOSITION OF FOODS

| | Water | Proteins | Fats | Carbo-hydrates | Salts |
|---|---|---|---|---|---|
| Beef, lean | 72 | 19.3 | 3.6 | ... | 5.1 |
| Beef, fat | 51 | 14.8 | 29.8 | ... | 4.4 |
| Mutton, lean | 72 | 18.3 | 4.9 | ... | 4.8 |
| Mutton, fat | 53 | 12.4 | 31.1 | ... | 3.5 |
| Veal | 63 | 16.5 | 15.3 | ... | 4.7 |
| Pork, fat | 39 | 9.8 | 48.9 | ... | 2.3 |
| Poultry | 74 | 21 | 3.8 | ... | 1.2 |
| Whitefish | 78 | 18.1 | 2.9 | ... | 1.0 |
| Salmon | 77 | 16.1 | 5.5 | ... | 1.4 |
| Eels (rich in fat) | 75 | 9.9 | 13.8 | ... | 2.7 |
| Oysters | 75.7 | 11.7 | 2.4 | ... | 2.7 |
| | | | | *Sugar* | |
| Milk | 86 | 4.1 | 3.9 | 5.2 | .8 |
| Buttermilk | 88 | 4.1 | .7 | 6.4 | .8 |
| Cream | 66 | 2.7 | 26.7 | 2.8 | 4.9 |
| Cheese, full | 36 | 28.4 | 31.1 | ... | 4.5 |
| Cheese, skim | 44 | 44.8 | 6.3 | ... | 4.9 |
| Eggs, white | 78 | 20.4 | ... | ... | 1.6 |
| Eggs, yolk | 52 | 16 | 30.7 | ... | 1.3 |
| | | | | *Starch* | |
| Bread | 37 | 8.1 | 1.6 | 51 | 2.3 |
| Flour | 15 | 10.8 | 2 | 70.8 | 1.7 |

**Alcohol and Longevity.** — Investigation by Baer has shown that the average expectation of life among users and dealers in alcoholic liquors is very much shortened. The following table gives a comparative view of the expectation of life in those who abstained from and those who used alcohol: —

## EXPECTATION OF LIFE

| Age | Abstainers | Alcohol Users |
| --- | --- | --- |
| At 25 | 32.08 years | 26.23 years |
| " 35 | 25.92 " | 20.01 " |
| " 45 | 19.92 " | 15.19 " |
| " 55 | 14.45 " | 11.16 " |
| " 65 | 9.62 " | 8.04 " |

## TABLE SHOWING THE INFLUENCE OF ALCOHOL UPON THE MORTALITY FROM VARIOUS DISEASES

| | General Male Population | Alcohol Venders |
| --- | --- | --- |
| Brain disease | 11.77 per cent | 14.43 per cent |
| Tuberculosis | 30.36 " | 36.57 " |
| Pneumonia and pleuritis | 9.63 " | 11.44 " |
| Heart disease | 1.46 " | 3.29 " |
| Kidney disease | 1.40 " | 2.11 " |
| Suicide | 2.99 " | 4.02 " |
| Cancer | 2.49 " | 3.70 " |
| Old age | 22.49 " | 7.05 " |

## THE MORE COMMON POISONS, THEIR SYMPTOMS, ANTIDOTES, AND TREATMENT

| Poisons | Symptoms | Antidotes and Treatment |
|---|---|---|
| Acids<br>Acetic<br>Citric<br>Muriatic<br>Nitric<br>Oxalic<br>Sulphuric<br>Tartaric | All highly corrosive, excoriating the parts with which they come in contact, occasioning intense pain, followed by symptoms of shock. Nitric acid makes yellow stains; sulphuric blackens. | For nitric and oxalic acids, the carbonate of magnesia or lime; for sulphuric acid, strong soapsuds; for oxalic, limewater; for the others, any dilute alkali. Induce vomiting, give demulcent drinks, and treat the consequent inflammation and shock as if from any other injury. |
| Carbolic | Caustic; whitening of the mucous membrane, with intense burning and numbness, nausea, weakness, stupor, and collapse. | Oil, milk. Secure rest, warmth of the body, and stimulation. |
| Alkalies and Earths<br>Ammonia<br>Baryta<br>Lime<br>Potash<br>Soda | Violent caustics, causing destruction of the mucous membrane, acute burning pain, vomiting and purging of bloody matter, and death by shock. | The vegetable acids — dilute vinegar, lemon-juice, etc. — neutralize them. The fixed oils — castor, linseed, olive, etc. — unite with them to form harmless soaps. Give these, and demulcent drinks, stimulants if necessary. |

THE MORE COMMON POISONS, THEIR SYMPTOMS, ANTIDOTES, AND TREATMENT
(*Continued*)

| Poisons | Symptoms | Antidotes and Treatment |
|---|---|---|
| METALLIC IRRITANTS | | |
| Antimony<br>*Tartar Emetic* | Symptoms like those of cholera; violent cramps and purging, collapse; inflammation of whole alimentary canal, with metallic taste, suppression of urine, vomiting, cramps, delirium or stupor, death. | Induce vomiting, if the poison has not already done so, and give astringent infusions, as of strong tea or oak bark. |
| Arsenic<br>*Paris Green*<br>*Scheele's Green*<br>*Fowler's Solution* | Intense pain, thirst, vomiting and purging, tenesmus, suppression of urine, clammy sweat, delirium or collapse, and death either in a few hours from shock, or after several days from inflammation. | The hydrated sesquioxide of iron — prepared by adding ammonia to the common muriated tincture, and washing the precipitate — is the antidote. Give *ad lib.* Or dialyzed iron and magnesia, half an ounce of each every ten minutes. After Fowler's solution, give limewater freely, evacuate the stomach, and give demulcents. |
| Bismuth<br>Copper<br>*Blue Vitriol*<br>*Verdigris* | Symptons like other irritants. | Emetics, milk, albumin, and mucilaginous drinks. |
| Iodine<br>Iron<br>*Copperas* | | Starch unites with iodine, forming an insoluble compound, but not with the iodide of potassium. |

| | | |
|---|---|---|
| Lead | May occasion paralysis. | |
| Mercury<br>*Corrosive Sub.*<br>*Vermilion* | | Albumin in some form, preferably the white of eggs, milk, flour gruel. |
| Phosphorus | | Emetics, mucilage, and magnesia. No oil. |
| Silver, *Nitrate of* | | May be decomposed by common salt. |
| Tin<br>Zinc<br>*White Vitriol* | | Carbonate of soda in solution, milk and albumin. |
| ANIMAL IRRITANTS<br>Cantharides | Severe pain and burning all through the alimentary canal, bloody evacuations, strangury, or retention of urine, convulsions, delirium, death. | Excite vomiting, give emollient drinks and enemata, but no oil. Rub the abdomen with camphor, or camphorated oil, to relieve the strangury. |
| Poisonous fish | Indigestion, headache, vertigo, thirst, vomiting, and diarrhea, collapse. Often an eruption on the skin. | Emetics, purgatives, and stimulants. |
| NARCOTICS and ACRO-NARCOTICS<br>Aconite<br>Alcohol<br>Belladonna (*Nightshade*)<br>Camphor<br>Chloral<br>Colchicum<br>Conium (*Hemlock*)<br>Digitalis (*Foxglove*) | These are nearly all vegetable poisons. They occasion nausea, numbness, stupor, delirium, or convulsions, overstimulation of the heart, followed by its failure, insensibility, coma, death. With the acro-narcotics, these symptoms are preceded by those of irritants, an acrid taste, constriction of the mouth and throat, fever, vomiting, and diarrhea, with intestinal pain. | Evacuate the stomach as thoroughly as possible, and give active purgatives; give strong coffee, and keep the patient roused. The custom of walking the patient up and down, and slapping with wet towels, is objectionable; it adds exhaustion to depression, and risks giving him pneumonia. Keep him in the recumbent position, and employ friction, and, if necessary, artificial respiration. |

## THE MORE COMMON POISONS, THEIR SYMPTOMS, ANTIDOTES, AND TREATMENT
(*Continued*)

| Poisons | Symptoms | Antidotes and Treatment |
|---|---|---|
| *Strychnine*<br>Physostigma<br>Opium<br>*Morphine*<br>Tobacco<br>Toadstools<br>Turpentine | Strychnia excites violent convulsions, like those of tetanus. | The spasms may be quieted by inhalation of ether. |
| Gases<br>Carbonic acid<br>Carbonic oxide<br>Nitrous oxide<br>Sulphureted hydrogen<br>Chlorine<br>Chloroform | Chlorine violently irritates the respiratory organs; the others act like narcotics. Each has a certain characteristic odor, by which it may be recognized. | Give plenty of fresh air, cautious inhalations of ammonia, stimulants, and artificial respiration if necessary. |

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